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PROPERTIES OF ALKALI BOROHYDRIDES. I. STABILITY IN HYDROXIDE SOLUTIONS[1]

JOHN B. BROWN[2a] AND MARGUERITE SVENSSON[2b]

ABSTRACT

The hydrolytic stability of potassium borohydride in solutions buffered at pH 12.45 has been studied. The rate of decomposition is first order with respect to borohydride and depends on the pH of the solution. Sodium, potassium or calcium cations apparently do not influence the rate of decomposition.

INTRODUCTION

The alkali borohydrides are crystalline, salt-like compounds containing the tetrahedral borohydride ion, BH_4^-, in a face-centered cubic lattice with an alkali metal ion. Considerable attention has been given to these compounds because of the reducing properties of the borohydride ion as well as their use in the preparation of various boron hydrides.

In 1949, Chaikin and Brown showed that sodium borohydride is an effective reagent for the reduction of certain organic compounds.[3] Subsequently, $NaBH_4$ has proved to be a convenient reagent which is practically specific for the carbonyl group of aldehydes, ketones and acid chlorides. In the realm of inorganic chemistry, $NaBH_4$ has been shown to reduce metal ions (1) to the next lower oxidation state in solution, (2) to an insoluble metal boride, (3) to a volatile metal hydride or (4) to the free metal.[4]

Potassium borohydride behaves in a manner quite analogous to sodium borohydride as a reducing agent,[4] but has some properties quite distinctly different from $LiBH_4$ and $NaBH_4$.[5] The potassium salt is less soluble in water than is $NaBH_4$, apparently does not form a stable hydrate from aqueous solutions and is non-hygroscopic. It is this last property that dictated the choice of KBH_4 for the borohydride compound to be investigated in these laboratories. The hygroscopic nature of $NaBH_4$ is such that dry-box facilities are almost necessary for a quantitative study of its properties.

In solution, the BH_4^- ion hydrolyzes according to

$$BH_4^- + 2H_2O \rightarrow BO_2^- + 4H_2. \qquad \text{(I)}$$

[1] Contribution from the Department of Chemistry, Denison University. A preliminary announcement of this work was published as a Communication to the Editor, *J. Am. Chem. Soc.*, **79**, 4241, 6581 (1957).

[2a] Assistant Professor of Chemistry, Denison University. [2b] Class of 1957, Denison University.

[3] S. W. Chaikin and W. G. Brown, *J. Am. Chem. Soc.*, **71**, 122–125 (1949).

[4] N. G. Gaylord, "Reduction with Complex Metal Hydrides," Interscience Publishers, Inc., New York, 1956; also *J. Chem. Educ.*, **34**, 367–374 (1957).

[5] M. D. Banus, R. W. Bragdon and A. A. Hinckley, *J. Am. Chem. Soc.*, **76**, 3848 (1954).

This hydrolysis can be accelerated by acids or certain metal catalysts.[6] It is generally stated in the literature that aqueous borohydride solutions are stable at a *p*H greater than 9,[6, 7] but quantitative data on this point are meager. Pecsok[8] has presented a study on the hydrolysis of $NaBH_4$ solutions buffered at various *p*H values between 7.7 and 9.5. Jensen[9] determined the stability of $NaBH_4$ in solutions buffered at *p*H 9.6 and 10.1 and of $NaBH_4$ dissolved in 1.00 *N*, 0.25 *N* and 0.10 *N* sodium hydroxide.

This paper presents results on the determination of the stability of KBH_4 solutions at *p*H 12.45.

EXPERIMENTAL PROCEDURES

A. Quantitative Determination of Borohydride

The assay of borohydride has been accomplished by methods based upon (1) a measurement of the hydrogen evolved upon acidification,[3] (2) a titration of the basic borohydride ion with dilute acid,[10] (3) an iodimetric titration,[11] (4) an iodometric titration,[12] (5) a direct titration with sodium hypochlorite,[13] (6) an argentimetric procedure,[14] (7) a potentiometric titration with permanganate[9] and (8) an amperometric titration.[8]

In a comparative study made by Jensen[9] on five of these procedures, it was found that the standard deviations of each method are comparable. Thus, it is difficult to generalize by saying that one method is better than others as each is especially good under certain specific conditions.

The hydrogen evolution method was selected for this experimental work for the relative simplicity of procedure and the wide range of conditions under which the reaction can take place.

B. Materials and Apparatus

It was desired that the first experiments be performed with solutions buffered at a high *p*H so that the reaction would proceed rather slowly and would be relatively easy to follow. It was contemplated that the study could be extended to less basic solutions after gaining experience with the procedure for borohydride assay.

The solvent chosen for these first experiments was a saturated solution of calcium hydroxide. Saturated calcium hydroxide at 25° C. has a *p*H of 12.45

[6] H. I. Schlesinger, *et al.*, *ibid.*, **75**, 215 (1953).

[7] H. R. Hoekstra, A. E. C. D. (June 1947).

[8] R. L. Pecsok, *J. Am. Chem. Soc.*, **75**, 2862–2864 (1953).

[9] E. H. Jensen, "A Study on Sodium Borohydride with Special Reference to its Analytical Application in Organic Chemistry," Nyt Fordisk Forlag, Arnold Busch, Copenhagen, 1954.

[10] W. D. Davis, L. S. Mason and G. Stegman, *J. Am. Chem. Soc.*, **71**, 2775–2781 (1949).

[11] M. B. Mathews, *J. Biol. Chem.*, **176**, 229–232 (1948).

[12] D. A. Lyttle, E. H. Jensen and W. A. Struck, *Anal. Chem.*, **24**, 1843–1844 (1952).

[13] S. W. Chaikin, *ibid.*, **25**, 831–832 (1953).

[14] H. C. Brown and A. C. Boyd, Jr., *ibid.*, **27**, 156–158 (1955).

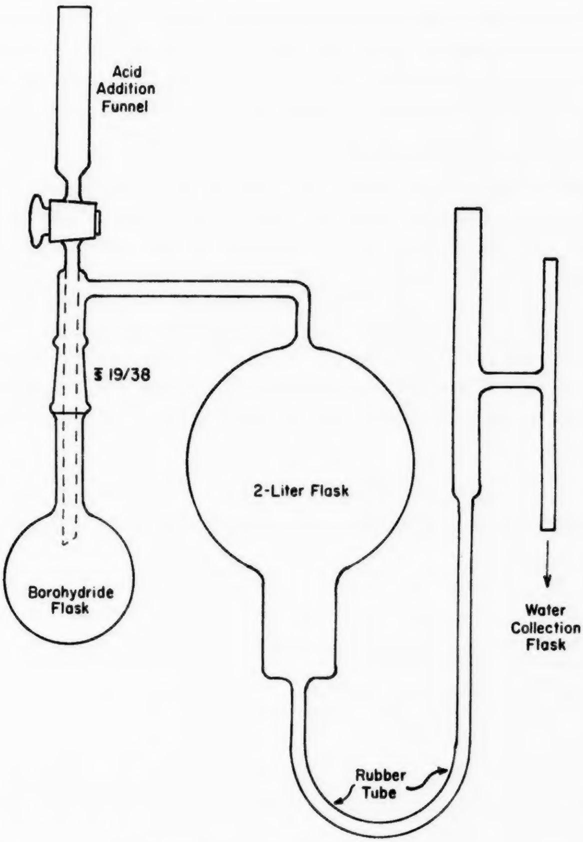


FIG. 1. Hydrogen Evolution Apparatus

and has recently been recommended as a highly alkaline buffer for defining the National Bureau of Standards *p*H scale.[15]

The calcium hydroxide solution was prepared by supersaturating de-ionized water with calcium oxide.* The solution was mixed thoroughly and allowed to stand several hours as the excess calcium oxide precipitated. The solution was filtered just prior to use.

Commercially available potassium borohydride† was used without further treatment.

The solutions were prepared by dissolving 0.1 mole KBH_4 in saturated $Ca(OH)_2$

[15] R. G. Bates, V. E. Bower and E. R. Smith, *J. Research Natl. Bur. Standards*, **56**, 305–312 (1956).

* J. T. Baker Co., C.P. Grade, Lot No. 4219.

† Metal Hydrides, Inc., Beverly, Mass., Lot No. K-12, Purity 97+%.

and diluting to one liter with additional solvent. Aliquot portions were removed from the flask with a 100-ml. pipet, transferred to 250-ml. flasks and stoppered.

One aliquot was analyzed immediately for borohydride content. The other flasks were suspended in a constant-temperature water bath maintained at 25.0 ± 0.1° C. At daily intervals, flasks were removed from the bath and the contents were analyzed for borohydride content.

The apparatus used for the assay of borohydride by hydrogen evolution is pictured in Figure 1. The 2-liter flask was filled with water through the "H-tube" and the flask containing borohydride attached to the apparatus by a 19/38 standard taper joint. The addition funnel was filled with dilute HCl (approximately 1 *N*). The system was brought to atmospheric pressure by adjusting the level of water in the "H-tube". Then the stopcock was opened to admit acid drop by drop to the reaction flask. The evolved hydrogen displaced water from the 2-liter flask and this water was collected in a previously weighed flask. The KBH_4 content of the sample was determined from the volume of evolved hydrogen.

C. Collection and Treatment of Data

During any given hydrolysis run, the following quantities were observed and recorded:

Barometric pressure,
Weight of water collection flask empty before run,
Weight of borohydride reaction flask before run,
Time of adding HCl to borohydride,
Weight of water collection flask after run,
Weight of reaction flask and HCl solution after run,
Temperature of collected water.

Data for run III-6 are presented below to illustrate the calculation of borohydride content of a solution analyzed by the hydrogen evolution method. The observed data were:

Weight of water collection flask after hydrolysis	1060.1 g
Weight of collection flask empty before hydrolysis	203.8 g
Weight of reaction flask after adding 1*N* HCl	197.0 g
Weight of borohydride solution in reaction flask before hydrolysis	180.1 g
Temperature of collected water	22.2°C
Barometric pressure	739.1 mm

The necessary supplementary data needed for the calculations were found in appropriate tables: (all at 22.2° C)

Specific volume of water[a]	1.0032 ml/g
Specific volume of 1*N* HCl[b]	0.9847 ml/g
Vapor pressure of water	20.0 mm

[a] Corrected for weighing in air with brass weights.

[b] Interpolated from tables of density of HCl solutions (weight per cent *vs*. temperature) given in "International Critical Tables," McGraw-Hill Book Co., Inc., New York, 1928; Volume III, page 54.

Thus, the volume of water in the collection flask at the end of the run was

$$(1060.1 - 203.8) \times 1.0032 = 859.0 \text{ ml},$$

and the volume of HCl added to accomplish the hydrolysis was:

$$(197.0 - 180.1) \times 0.9847 = 16.6 \text{ ml}.$$

The volume of hydrogen (corrected to standard conditions) liberated from this solution was then calculated:

$$(859.0 - 16.6) \times (273/295.2) \times [(739.1 - 20.0)/760] = 737.2 \text{ ml. } H_2.$$

The stoichiometric relation for the reaction is

$$KBH_4 + HCl + 3H_2O \rightarrow B(OH)_3 + KCl + 4H_2.$$

The amount of KBH_4 is thus related to the volume of evolved hydrogen by

$$\text{mg. } KBH_4 = V_{H_2}\,(53952/22429.9)(1/4) = 0.6013\,V_{H_2}$$

where V_{H_2} is the volume of evolved hydrogen measured in milliliters. The factor 22429.9 is the volume in ml. of a mole of H_2 at S.T.P. based on the density of 0.08988 grams per liter[16] and 53952 is the weight of a mole of KBH_4 in milligrams.

Thus, the borohydride content of sample III-6 (94.416 hours after preparation of the solution) was calculated:

$$KBH_4 \text{ content} = 0.6013 \times 737.2 = 443.3 \text{ mg}.$$

The zero of time for a given series of experiments was the time of preparation of the solution and for practical purposes was identical with the initial determination of borohydride. The time of adding acid to the borohydride solution was observed for purposes of determining the elapsed time between analyses.

An analysis of the probable errors of observed quantities indicates that the uncertainty of borohydride content for this procedure was about 0.4 per cent.

Although it was expected from Pecsok's work[8] that the reaction would be first order with respect to borohydride, a simple plot of borohydride content *vs.* time appeared to be linear. This would fit the condition for a zero order reaction. Series IV was planned to test the linearity of a concentration *vs.* time relationship. After a run of 450 hours, the concentration *vs.* time plot showed a definite curvature, but the logarithm of concentration was a linear function of time. These two curves are shown in Figure 2. The reason for the apparent linearity of the concentration with time was that the rate constant for the reaction is so small that almost any function of concentration is linear with time for relatively short time periods.

For each of the stability series, a plot of the logarithm of KBH_4 content *vs.* time was made and the data were fitted to an analytical expression by the

[16] "International Critical Tables," McGraw-Hill Book Co., Inc., New York, 1928; Volume III, page 3.

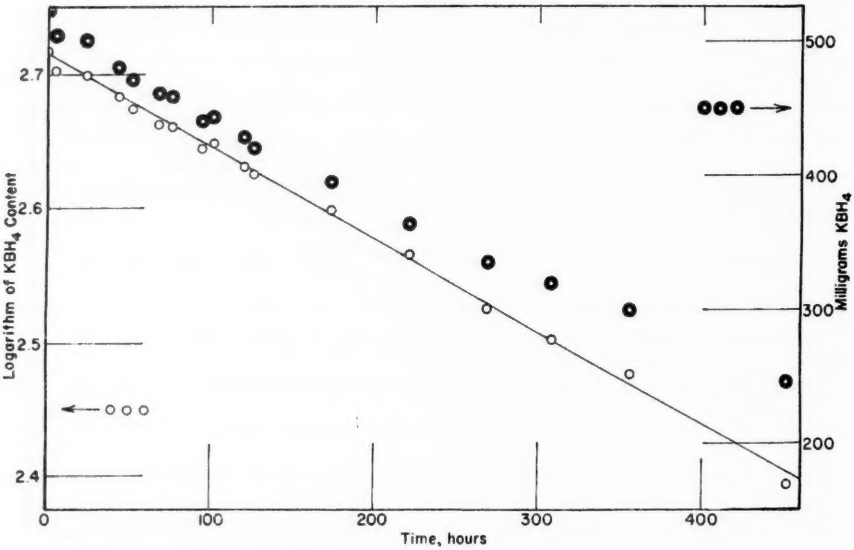


FIG. 2. Decomposition of potassium borohydride as a function of time. Concentration of solution expressed as logarithmic function on left ordinate. Data for Series IV.

method of least squares.[17] The points which were suspected of representing nonrandom experimental error were tested by the Pierce-Chauvenet criterion[17] before they were rejected.

EXPERIMENTAL RESULTS

The results of the four series of stability determinations are presented in Table I. Series IV was shown in Figure 2. Figure 3 gives the logarithmic plot of the data for the other three series.

Table II summarizes the least square analyses to determine the slopes of the log concentration *vs.* time plots. The probable error tabulated in Table II is the probable departure of any given point from the value calculated from the least-square line. The probable error was calculated from the formula

$$r = \pm 0.675\sqrt{\Sigma d^2/(n - k)}$$

given by Crumpler and Yoe.[17] In this formula, d is the deviation of the experimental point from the least-square calculation, n is the number of points used to obtain the least-square fit, and k is the number of constants in the fitted equation (in this case, $k = 2$).

If the hydrolysis reaction (Equation I) is first order with respect to borohydride ion, then

[17] Thomas B. Crumpler and John H. Yoe, "Chemical Computations and Errors," John Wiley and Sons, Inc., New York, 1940.

TABLE I

Results of Borohydride Analyses

Conditions: Temperature maintained at 25.0 ± 0.1° C., KBH_4 dissolved in saturated $Ca(OH)_2$ and analyses made on 100-ml. aliquots.

Run	Series I		Series II		Series III		Series IV	
	Time hrs., min.	KBH_4 mg.	Time hrs., min.	KBH_4 mg.	Time hrs., min.	KBH_4 mg.	Time hrs., min.	KBH_4 mg.
1	0:30	494.8	0:15	511.8	0:10	507.9	0:05	523.4
2	16:17	485.3	16:40*	536.6*	17:00*	521.8*	5:05	504.8
3	45:05	470.0	45:15	493.3	28:30*	500.0*	24:20	500.6
4	69:30	448.8	69:00	473.7	47:45	Leak	43:05	482.5
5	95:45*	442.9*	92:10	Leak	72:50	464.6	52:05	471.9
6	117:10	415.8	97:10	454.6	94:25	443.3	68:35	462.6
7	163:30	392.0	112:10	433.1	124:02	433.0	76:35	459.7
8	214:20*	298.1*	136:00*	402.1*	166:20	404.2	94:35	440.8
9			185:15	395.9	192:15	392.5	101:50	444.9
10							120:35	428.5
11							126:20	421.7
12							173:35	395.5
13							221:20	368.7
14							269:35	336.1
15							308:35	319.8
16							356:20	300.1
17							412:20*	238.2*
18							451:35	247.8

* Data rejected from least square analyses by the Pierce-Chauvenet criterion.

TABLE II

Least Square Analyses of Stability Data

Series	Least Square Equation (mg KBH_4 in 100 ml; time in hrs)	Probable Error	First Order Rate Constant, k' (reciprocal hrs)
I	$\log KBH_4 = 2.6959 - 0.000628\,t$	±0.002	0.00145
II	$\log KBH_4 = 2.7068 - 0.000533\,t$	±0.006	0.00123
III	$\log KBH_4 = 2.7067 - 0.000588\,t$	±0.002	0.00136
IV	$\log KBH_4 = 2.7142 - 0.000689\,t$	±0.003	0.00159

$$-d(BH_4^-)/dt = k'(BH_4^-) \qquad \text{(II)}$$

and

$$\ln (BH_4^-) = \ln (BH_4^-)_0 - k't.$$

Conversion to common logarithms of base 10 then results in

$$\log (BH_4^-) = \log (BH_4^-)_0 - (k'/2.303)t.$$

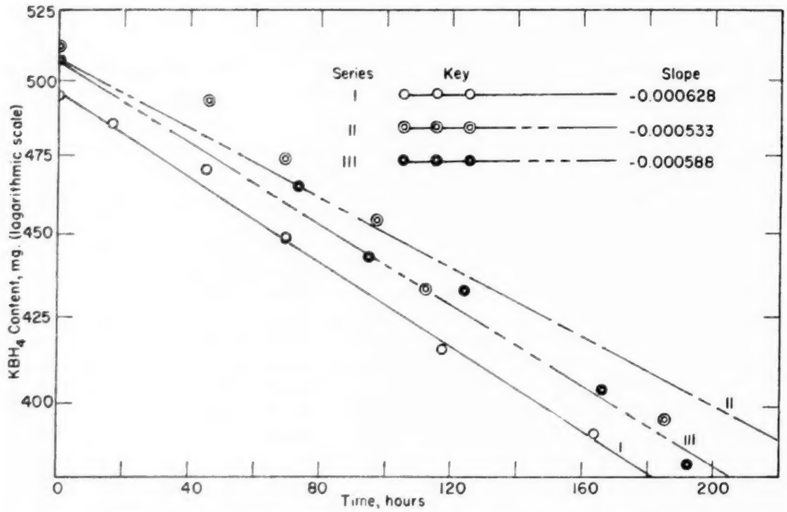


FIG. 3. Stability of KBH_4 in saturated $Ca(OH)_2$ solutions at 25° C

The quantity $(BH_4^-)_0$ is the concentration of borohydride ion at time equal to zero.

Thus the slopes, K, of the lines in Figures 2 and 3 are related to the first-order rate constant, k', by

$$k' = 2.303\ K.$$

Values of the first-order rate constant, k', are given in Table II along with the least-square expressions for the lines through the experimental data.

DISCUSSION

A. Stability of Borohydride in Highly Alkaline Hydroxide Solutions

Jensen has reported data on the stability of 0.10 M sodium borohydride in NaOH solutions at 24° C.[9] As was the case in the present work, Jensen did not measure the pH of the solutions which were 1.00 N, 0.25 N and 0.10 N in sodium hydroxide. The pH of these solutions may be calculated from the formula given by Bates:[18]

$$pH_s = -\log K_w + \log m_{OH}f_{NaOH} \qquad \text{(III)}$$

where pH_s is the defined pH of the solution. Values of K_w, the ionization constant of water at atmospheric pressure, and of f_{NaOH}, the mean activity coefficient

[18] Roger G. Bates, "Electrometric pH Determinations," John Wiley and Sons., Inc., New York, 1954, page 86.

TABLE III

Stability of 0.1 M $NaBH_4$ in NaOH Solutions at 24°C

NaOH Conc.	*p*H	*K*, Slope First Order Plot (log BH_4^- content *vs.* time)	First Order Rate Constant, $k' = 2.303\,K$ (reciprocal hours)
1.00 *M*	13.8	1.72×10^{-4}	3.97×10^{-4}
0.25 *M*	13.3	3.07×10^{-4}	7.08×10^{-4}
0.10 *M*	12.9	4.23×10^{-4}	9.74×10^{-4}

of NaOH in aqueous solutions of different molal concentrations (m_{OH}), are given by Harned and Owen.[19]

A logarithmic plot of Jensen's data indicates that the first-order kinetics of Equation II are also applicable to these data. Table III summarizes Jensen's data for the stability of $NaBH_4$ in NaOH solutions. The *p*H was calculated from Equation III; the slopes, *K*, of the first-order plots were determined by a least-square analysis of Jensen's data.

Jensen's data were expressed as a per cent of the original amount of $NaBH_4$ present. In the present work, the concentration has been expressed as the milligrams of KBH_4 contained in 100 ml. solution. Even so, the first-order rate constants, k', of Table II are directly comparable with those of Table III because the rate constant of a first-order reaction is independent of the units of concentration.

The logarithms of these rate constants are a linear function of the *p*H of the solution (see Figure 4) and fit the relation

$$-\log k' = -2.333 + 0.4\,p\text{H}. \qquad \text{(IV)}$$

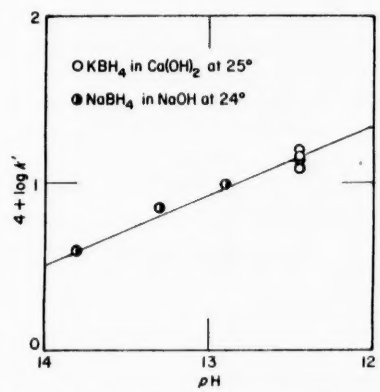


FIG. 4. Variation of first-order rate constant, k', of Equation II as a function of *p*H. Borohydride dissolved in hydroxide solutions.

[19] H. S. Harned and B. B. Owen, "The Physical Chemistry of Electrolytic Solutions," Reinhold Publishing Corp., New York, 1943, pages 485 and 560.

From Figure 4, it can be concluded that the rate of hydrolysis of the borohydride ion at any given pH is independent of the presence of Na^+, K^+ or Ca^{++} cations. And, combining Equation IV with Equation II, the stability of borohydride in hydroxide solutions at room temperature (24–25°) can be represented by

$$-d(BH_4^-)/dt = 215\ (BH_4^-)\ (H_3O^+)^{0.4}. \qquad \text{(V)}$$

It should be recognized that the rate constant in Equation V (215 liters mole^{-1} hour^{-1}) is not strictly correct since the concentration of hydronium ion, (H_3O^+) is not exactly equal to the activity of hydronium ion (pH) as defined by Equation III.

B. Stability of Borohydride in Buffered Solutions

Jensen has also presented data for the stability of $NaBH_4$ solutions in borate buffers at 24° C.[9] Pecsok studied the hydrolysis of $NaBH_4$ in pyrophosphate buffers[8] at 15°, 25° and 35° and concluded that the mechanism of the hydrolysis can be expressed by:

$$BH_4^- + H_3O^+ + xH_2O \rightarrow HBH_4 \cdot xH_2O \qquad \text{(slow)}$$

$$HBH_4 \cdot xH_2O \rightarrow H_2 + BH_3 \cdot xH_2O \qquad \text{(fast)}$$

$$BH_3 \cdot xH_2O + 3H_2O \rightarrow B(OH)_3 + 3H_2 + xH_2O \qquad \text{(fast)}$$

The rate equation at 25° was found to be

$$-d(BH_4^-)/dt = 1.5 \times 10^7\ (BH_4^-)(H_3O^+).$$

Jensen's data were analyzed as above to determine the first-order rate constants, k'. It is possible to redetermine Pecsok's first-order constants at any pH from the value of the second-order rate constant, $k' = k\ (H_3O^+)$. Pecsok's data were in terms of time measured in minutes; in Jensen's work and in this study time was measured in hours. For comparison with the present work, Pecsok's data were converted to time measured in hours.

Table IV summarizes the first-order rate constants at different pH values

TABLE IV

First Order Rate Constants for Decomposition of Buffered $NaBH_4$ Solutions

A. Jensen's data with borate buffer at 24°:

pH	Initial Conc. $NaBH_4$	K, Slope of First Order Plot (log BH_4^- *vs.* time)	First Order Rate Constant, $k' = 2.303\ K$ (reciprocal hours)
9.6	0.01 M	6.57×10^{-2}	0.151
10.1	0.10 M	2.31×10^{-2}	0.053

B. Pecsok's data with pyrophosphate buffer at 25°:
Oxygen-free 0.001 M $NaBH_4$ solutions at constant ionic strength, $\mu = 0.1$; rate constants converted from Pecsok's original units of min.$^{-1}$ to reciprocal hours.

pH	7.7	8.2	9.0	9.3	9.5
k', first order rate constant (hrs.$^{-1}$)	18	5.67	0.90	0.45	0.28

determined by Jensen and by Pecsok in buffered solutions. The relation between log k' and pH for these data is shown in Figure 5.

In the buffered solutions, Jensen's data support Pecsok's conclusion that the decomposition is first order with respect to hydronium ion as well as first order with respect to borohydride. Also, these data support Hoekstra's conclusion[7] that, in the pH range below 9, the hydrolysis is independent of the type of buffer system used.

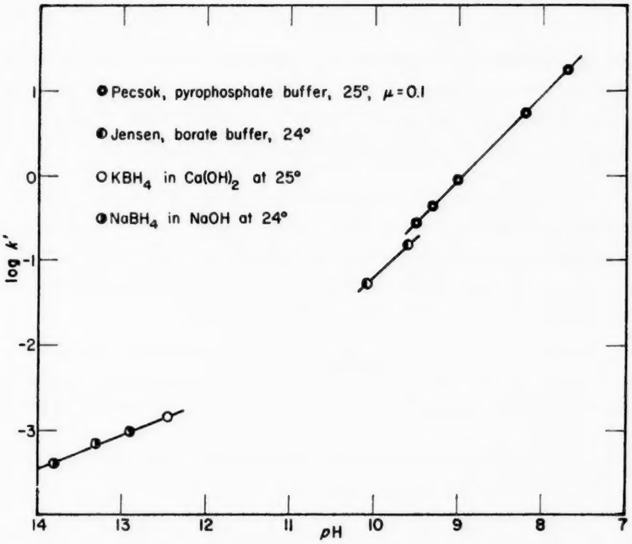


FIG. 5. Logarithm of first-order rate constants as a function of pH for hydrolytic stability of borohydride in various basic solutions.

ACKNOWLEDGEMENTS

We are grateful to the Denison University Research Foundation for financial assistance and to Metal Hydrides, Inc. for experimental samples of KBH_4 used in this work. A copy of Dr. Jensen's book was made available to us by the Callery Chemical Co. The hydrogen evolution apparatus was constructed and used according to the suggestions of Mr. James B. Vetrano of Battelle Memorial Institute. Miss Jennifer King contributed to the continuity of the work by executing some of the borohydride analyses.

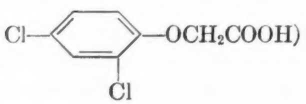
THE SYNTHESIS AND EVALUATION OF SOME PLANT GROWTH SUBSTANCES RELATED TO 2,4-D AND 2,4,5-T[1]

EARL BERRY,[2] HOWARD LEE,[3] ELLIOTT MILLER[4] AND DWIGHT R. SPESSARD[5]

ABSTRACT

Four new di- and trichlorophenyl ω-bromoalkyl ethers, related to 2,4-D and 2,4,5-T, have been synthesized and characterized. These in turn have been treated with triethyl phosphite in an Arbuzov-Michaelis type of reaction to produce four new diethyl chlorophenoxyalkylphosphonates which were then also characterized. Good values for the saponification equivalent of one of these esters have been obtained. The saponification product isolated is believed to be the sodium salt of the half ester. Four of the eight new compounds that have been synthesized have been evaluated in straight growth tests, utilizing the first internode sections of oat seedlings. All have been shown to possess slight auxin activity at one or more of the concentrations tested.

INTRODUCTION

A number of modifications in the 2,4-D molecule (2,4-dichlorophenoxyacetic acid,  have been suggested and tried out as potential herbicides. Although 2,4-D is a highly effective and widely used herbicide, it has certain limitations due to its high selectivity in the types of weeds it kills, and also due to its relative short period of effectiveness. It is believed to lose its activity through decarboxylation.

It was therefore felt that it might be profitable to synthesize, if possible, molecules closely related to 2,4-D, but containing phosphonic acid groups instead of a carboxyl group. Such compounds might be effective longer and have a different specificity for certain types of plants. Furthermore, it would be a means of intro-

[1] This work was presented, in part, as a paper at the Ohio Academy of Science meeting held at Springfield, O., April, 1956.

[2] Class of 1956, Denison University. Present address Northwestern University Medical School, Chicago, Illinois.

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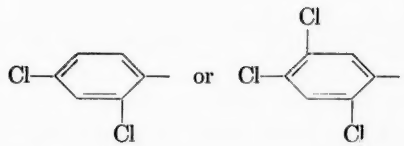
[4] Class of 1954, Denison University. Present address Harvard University Medical School, Cambridge, Massachusetts.

[5] Associate Professor of Chemistry, Denison University, Granville, Ohio.

ducing phosphorus into plants. It is a well-known fact that phosphorus, in the form of organophosphates at least, plays a vital role in plant biochemistry. In addition to the compounds related to 2,4-D, it was decided to prepare analogs of 2,4,5-T, and compounds with varying numbers of methylene groups between the phenoxy oxygen and the phosphonic acid group. The general type of molecule, therefore, that would be synthesized in this study was to be:

$$\mathrm{Ar{-}O{-}(CH_2)_x{-}P(O)(OR)_2} \qquad \textbf{(I)}$$

where

Ar = 

$\mathrm{R = C_2H_5{-}}$ or $\mathrm{H{-}}$

$x = 1, 2,$ or 3

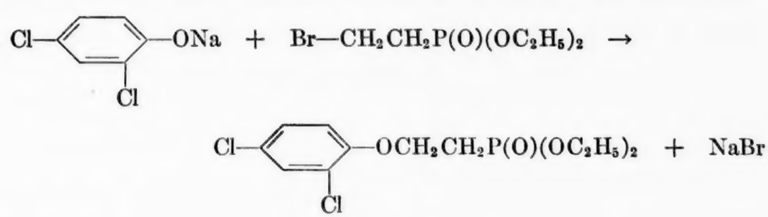
Another and equally important goal of this research was to study and extend the knowledge of organophosphorus chemistry, especially as related to certain phosphonic acids and esters.

As indicated above, it had been planned to synthesize type I compounds where x = 1, but due to some difficulty and high cost in synthesizing the intermediates, this was postponed after a few preliminary experiments. After most of our other work was completed, these phosphonates, $\mathrm{Ar{-}O{-}CH_2{-}P(O)(OR)_2}$, homologs of the compounds described in our paper, were reported by Maguire and Shaw (1, 2).

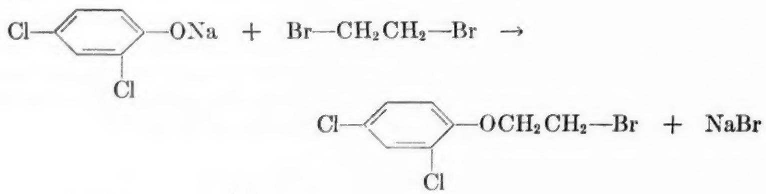
Among the various methods that were considered for synthesizing type I compounds, two methods seemed to be the most promising. These are represented by the following sets of equations:

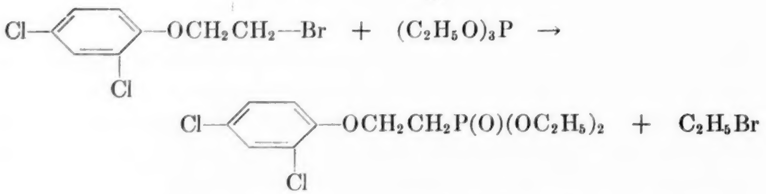
Method A.

1. $\mathrm{Br{-}CH_2CH_2{-}Br + (C_2H_5O)_3P \rightarrow Br{-}CH_2CH_2P(O)(OC_2H_5)_2 + C_2H_5Br}$

2. 

Method B.

3. 

4. 

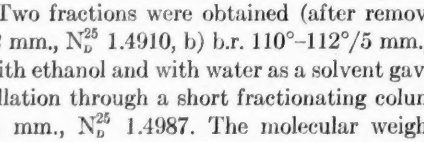
In equations 2 and 3 above it would seem likely that sodium 2,4,5-trichlorophenoxide could be substituted for sodium 2,4-dichlorophenoxide; and in equation 3. it would be expected that 1,3-dibromopropane (and other alkylene dihalides) might be substituted for 1,2-dibromoethane.

EXPERIMENTAL

Reaction of Diethyl Bromoethylphosphonate With Sodium 2,4-Dichlorophenoxide

Metallic sodium (2.3 g., 0.1 mole) was dissolved in 100 ml. of absolute ethanol in a 200 ml. three-neck flask equipped with a reflux condenser, mechanical stirrer, and thermometer. 2,4-dichlorophenol[6] (16.3 g., 0.1 mole) was then added. When this had dissolved, diethyl bromoethylphosphonate[7] (25.0 g., 0.1 mole) was added and the mixture heated to between 70° and 80°C. for one hour. The precipitated sodium bromide was filtered off (9.0 g., 0.087 mole) and the mixture distilled. Two fractions were obtained (after removal of the ethanol): a) b.r. 100°–102°/2 mm., N_D^{25} 1.4910, b) b.r. 110°–112°/5 mm., N_D^{25} 1.4950. Subsequent runs, both with ethanol and with water as a solvent gave a similar product, which after a distillation through a short fractionating column, gave a fraction boiling at 95°C./1 mm., N_D^{25} 1.4987. The molecular weight of this material (determined cryoscopically in benzene) was about 310; and it was found by qualitative analysis to contain both chlorine and phosphorus.

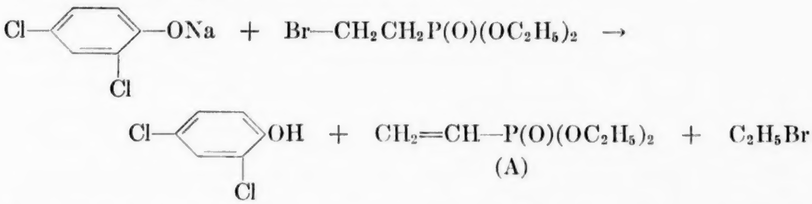
From the boiling point (much too low for a compound having a molecular weight of 310), it was decided that the product could not be



[6] Obtained from Eastman, m. r. 40° to 42° C.

[7] Prepared by the method described by Kosolapoff (3) by reacting 1,2-dibromoethane (Eastman, pract. grade) with triethyl phosphite. See equation 1., Method A. in the INTRODUCTION.

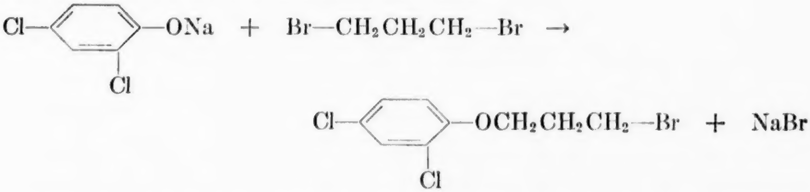
m.w. 327, although the possibility remained that the desired product might be present as an azeotrope, perhaps with 2,4-dichlorophenol. The phenol could be accounted for by a side reaction:



Some diethyl vinylphosphonate (A) was also obtained during the purification procedure, which adds weight to this theory. More work needs to be done to establish definitely the identity of the main reaction product that forms in the reaction between sodium 2,4-dichlorophenoxide and diethyl bromoethylphosphonate.

Reaction of Sodium Chlorophenoxides with Alkylene Dibromides

Formation of ω-Bromoalkyl Chlorophenyl Ethers



It was decided that it might be more profitable to go to another method for the synthesis of the desired phosphonate esters, i.e. Method B, INTRODUCTION.

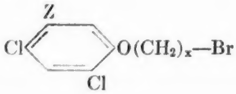
The preparation of ω-bromoalkyl phenyl ethers has been described in the literature (4, 5), although the preparation of the corresponding 2,4-dichlorophenyl- and the 2,4,5-trichlorophenyl ethers has not. It was found that by refluxing an excess of the alkylene dibromide (either 1,2-dibromoethane or 1,3-dibromopropane) with the sodium chlorophenoxides until a significant drop in *p*H occurred, good yields of bromoethers could be obtained, with little of the diether forming. In this way the four new bromo ethers listed in Table I were prepared.

A typical procedure follows: In a 200 ml. three-neck flask equipped with a mechanical stirrer, reflux condenser, and pipette for withdrawing samples to measure the *p*H, were placed 2,4,5-trichlorophenol[8] (30.8 g., 0.16 mole) and 25 ml. of 25% aqueous sodium hydroxide solution (0.16 mole NaOH). When the phenol had dissolved 1,3-dibromopropane[9] (63.0 g., 0.31 mole) was added. The initial *p*H of the solution was greater than 11. The mixture was refluxed and the

[8] Obtained from Eastman, pract. grade, m. r. 57° to 63°C.

[9] Obtained from Eastman, pract. grade.

TABLE I

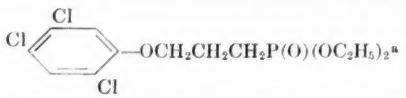
Chlorophenyl ω-bromoalkyl ethers, 

Z	x	Yield	B.p.		N_D^{25} (or M.p.)	Carbon, %[a]		Hydrogen, %		Total Halogen (% Cl + % Br)	
			°C.	Mm.		Calcd.	Found	Calcd.	Found	Calcd.	Found
H	2	65%	113.5	0.5	1.5788	35.59	35.69	2.61	2.75	55.87	55.40
H	3	90%[b]	140	3.0	1.5684	38.06	37.96	3.19	3.22	53.11	52.70
Cl	2	74%	173	5.0	56.5°C.	31.56	31.49	1.99	1.89	61.19	61.30
Cl	3	80%	185	5.0	54°C.	33.94	34.11	2.53	2.53	58.50	58.65

[a] The analytical data in this table and in Table III were obtained by Drs. Weiler and Strauss, Oxford, England.
[b] Based on unrecovered 2,4-dichlorophenol.

TABLE II

Preparation of diethyl γ-(2,4,5-trichlorophenoxy)-propylphosphonate



Ratio 1,3-dibromopropane to phenol	Reaction Time (Hours)	Final pH	% Yield Bromoether	Amount Residue (grams)
1:1	1.00	7	67	6.7
1.5:1	1.25	7	76	4.1
2:1	1.17	7	78	3.3
5:1	1.25	7	78	v. small
2:1	0.50	9	75	3.0
2:1	2.17	1	80	2.8

[a] 0.16 molar runs were made in all of the reactions listed above.

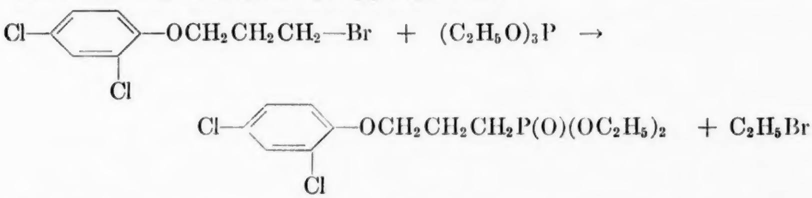
course of the reaction followed by periodically measuring the pH of the aqueous layer with Hydrion pH paper. The reaction was stopped after 70 minutes of refluxing, the pH being 7. 40 ml. of 14 % aqueous sodium hydroxide solution were added directly to the reaction vessel and the mixture maintained between 50° and 70°C., with stirring, for 30 minutes. The mixture was then transferred to a separatory funnel, the aqueous layer separated, and the organic layer washed five times (or until washings were neutral) with water. The wet organic layer was then distilled directly under vacuum. After recovering 26 g., 82.5 % of the excess 1,3-dibromopropane, the crude 3-bromopropyl 2,4,5-trichlorophenyl ether was obtained, boiling from 160°–180°/5 mm., with most of the product distilling at 175°/5 mm., yield 78 %. Variations in the length of reflux time (and hence the final pH of the solution) and in the ratio of 1,3-dibromoalkane to 2,4,5-trichlorophenol were made in a series of reactions listed in Table II. It is evident that after

a drop in pH to 9, there is not a great deal to be gained by running the reaction longer. A ratio of 1,3-dibromopropane to phenol of 2:1 appears desirable. When lesser amounts of 1,3-dibromopropane were used, the amount of residue (presumably diether) increased and the yield of desired product decreased slightly.

The other three bromo ethers listed in Table I were prepared in a manner similar to the one above; i.e. both 1,2-dibromoethane and 1,3-dibromopropane reacted with 2,4-dichlorophenol and 2,4,5-trichlorophenol by the procedure described to give good yields of the bromo ethers. It is believed that the variations in reaction conditions described above would apply equally well to the formation of these other ethers. Several runs were made in preparing each ether; and the yields listed in Table I were typical and were for crude products. The physical constants and analytical data were made on samples purified by several simple vacuum distillations and a fractionation through a short (6″) fractionating column packed with glass helices.

Reaction of Bromoalkyl Chlorophenyl Ethers with Triethyl Phosphite

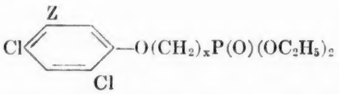
The Formation of Chlorophenoxyalkylphosphonates.



The four bromo ethers prepared as described in the previous section were refluxed with triethyl phosphite in an Arbuzov-Michaelis type reaction (6) in order to synthesize the phosphonate esters listed in Table III. The apparatus used was similar to that described by Kosolapoff (3). In a typical preparation, triethyl phosphite[10] (71 g., 0.43 mole) and 3-bromopropyl 2,4-dichloro-phenyl ether (55 g., 0.19 mole) were refluxed for 82 minutes, the mixture being stirred magnetically. The reaction temperature ranged from 152° to 169° C. The course of the reaction was followed by measuring the amount of ethyl bromide evolved, with slightly over 13 ml. (91% of theoretical) being collected in this case. Vacuum distillation of the remaining reaction mixture yielded (after removal of the excess triethyl phosphite) 62.1 g., 94% yield, of crude diethyl γ-(2,4-dichlorophenoxy)-propylphosphonate. In the syntheses of the other phosphonate esters similar conditions were employed (with reaction temperatures often being taken up to 200°C., or slightly higher, for a brief period at the end of the reaction); and comparable yields were obtained in most cases. The best yields were obtained when the molar ratio of triethyl phosphite to bromoether was 1.5:1 to 2:1. In the case of diethyl β-(2,4,5-trichlorophenoxy)-ethylphosphonate where the yield was only 55%, only two runs were made (both in the early stages of this phase of the problem) and in both cases equal molar ratios of triethyl phosphite and

[10] Obtained from the Virginia-Carolina Chemical Co.

TABLE III

Diethyl chlorophenoxyalkyl phosphonates, 

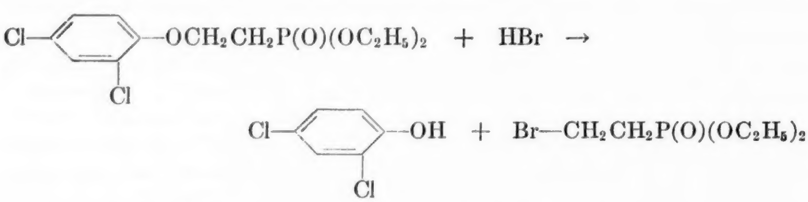
Z	x	Yield	B.P.		N_D^{25}	D_4^{25}	M. R.		Carbon, %		Hydrogen, %		Chlorine, %[a]	
			°C.	Mm			Calcd.	Found	Calcd.	Found	Calcd.	Found	Calcd.	Found
H	2	86%	160	0.5	1.5152	1.2794	76.26	77.13	44.05	44.19	5.24	5.22	21.68	21.50
H	3	94%	166	0.5	1.5126	1.2514	80.88	81.27	45.76	46.02	5.61	5.63	20.78	20.55
Cl	2	55%	187	0.5	1.5281	—	—	—	39.86	40.12	4.46	4.57	29.42	29.50
Cl	3	94%	197	1.5	1.5245	—	—	—	41.57	41.91	4.83	4.93	28.32	28.20

[a] Presence of phosphorus determined qualitatively; due to high percentage of chlorine, phosphorus could not be determined quantitatively by standard procedure.

bromo ether were employed. The physical properties and analytical data given in Table II are for samples purified by several simple vacuum distillations. Proof of structure was established for two of the phosphonate esters from molecular refractivities.

Hydrolysis of Phosphonate Esters

Various methods of hydrolysis were attempted in an effort to obtain the chlorophenoxyalkylphosphonic acids from the corresponding diethyl esters. Refluxing with concentrated hydrochloric and hydrobromic acids for prolonged periods (up to 42 hours) failed to yield any crystallizable product. Usually a phenolic odor developed during these hydrolyses, indicating cleavage at the ether linkage. The suggested course of this reaction is:



with the diethyl bromoethylphosphonate probably hydrolyzing further to the corresponding phosphonic acid.

Next, various concentrations of aqueous sodium hydroxide were tried. Most of these experiments were carried out with diethyl γ-(2,4-dichlorophenoxy)-propylphosphonate, by refluxing this compound with aqueous sodium hydroxide of varying concentrations. Saponification did occur, and upon acidification with hydrochloric acid, a salt-like material with very high melting point (>300°C.), insoluble in a great variety of organic solvents, precipitated. This solid was not purified nor has it been identified. No odor of phenol was noted during these alkaline hydrolyses and subsequent acidifications, nor was there any removal of

TABLE IV

Saponification of diethyl-γ-(2,4-dichlorophenoxy)-propylphosphonate with aqueous NaOH

Wt. Sample Saponified (Grams)	*N* of NaOH Used	Time of Saponification (Hours)	Saponification Equivalent Found*
0.6542	1.126	4.4	543
0.6106	1.126	5.0	490
0.5477	1.126	10.0	365
1.3685	2.200	5.1	441
1.3626	2.866	5.0	394

* Saponification equivalent (theoretical, assuming formation of Na salt of half ester) 341.2.

aromatic chlorine. These hydrolyses (saponifications) presumably produced the sodium salt of the half ester, Ar—O—$(CH_2)_x$—$P(O)(OC_2H_5)(ONa)$, although these reactions were not quantitatively complete, even after refluxing for 10 hours with approximately 11.5% aqueous NaOH. A number of these saponifications, carried out analytically, in which the excess alkali was back titrated (potentiometrically) with hydrochloric acid, are summarized in Table IV. The stoichiometric end-point (in the titration curves) was at *p*H 6.4 to *p*H 7.0.

Finally it was decided to use an ethanolic solution of sodium hydroxide to hydrolyze the phosphonate ester. Here saponification to the sodium salt of the half ester appeared to be complete after refluxing for 2½ hours with 0.6661 *N* ethanolic sodium hydroxide. No further reaction occurred after refluxing for 6 hours. Again the material that precipitated out during the back titration of the excess alkali with hydrochloric acid appeared to be the sodium salt of the half ester (melting point > 300°C.). Saponification equivalent: found—342.5, theoretical—341.2.

Evaluation of Synthesized Compounds As Plant Growth Substances

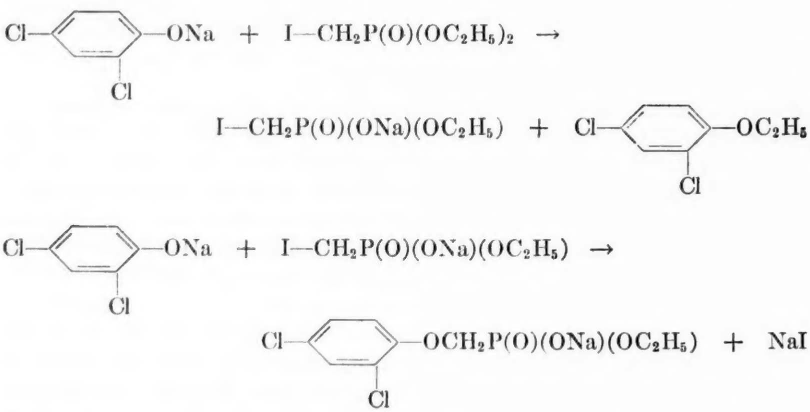
There are numerous ways of evaluating plant growth substances. Auxins are frequently evaluated quantitatively for growth promoting activity and highly sensitive tests of this type have been developed (7, 8). In addition, compounds of possible use as herbicides are frequently screened qualitatively and semi-quantitatively for their gross plant growth effects on such plants as tomatoes, beans, cucumbers, et cetera (9).

To date, four of the eight compounds that have been synthesized have been evaluated for growth promoting activity, using a straight growth test involving the first internode sections of oat seedlings. Tests were carried out with aqueous solutions of these compounds ranging in concentration from 0.01 mg/liter to 10 mg/liter. At one or more concentrations, all of the compounds tested showed some slight positive growth activity (compared to blanks or controls), although far less than the auxin, indole acetic acid. The compounds tested were:

1) 2,4-dichlorophenyl 2-bromoethyl ether
2) 2,4-dichlorophenyl 3-bromopropyl ether
3) diethyl β-(2,4-dichlorophenoxy)-ethylphosphonate
4) diethyl γ-(2,4-dichlorophenoxy)-propylphosphonate

DISCUSSION OF RESULTS

The reaction between diethyl bromoethylphosphonate and sodium 2,4-dichlorophenoxide has been investigated, in part; and although the exact course of the reaction is not known, it appears to be considerably different from the reaction reported by Maguire and Shaw (1) for diethyl iodomethylphosphonate and sodium 2,4-dichlorophenoxide. In this latter reaction, it was stated that de-esterification of one of the phosphonic ester groups occurred first, followed by ether formation.



There thus appears to be a considerable difference in reactivity of haloalkylphosphonates, depending upon whether the halogen is located alpha or beta with respect to the phosphorus atom.

Hydrolysis of chlorophenoxyalkylphosphonate esters in acid solution also appears to be considerably different, depending upon whether or not the chlorophenoxy group is on a carbon atom that is alpha to the phosphorus of the phosphonate ester group. When the chlorophenoxy group was on the alpha carbon the compounds were found to hydrolyze at the phosphonic ester group, giving the corresponding phosphonic acid (1). In the case where the chlorophenoxy group is located on a carbon atom beta (or even gamma) to the phosphorus, there is much more tendency for the ether linkage to split. In these latter types of compounds it does appear possible to saponify the phosphonic ester, at least to the sodium salt of the half ester, in ethanolic sodium hydroxide.

In the evaluation studies it was interesting to note slight auxin activity with the chlorophenoxy bromoalkyl ethers (prepared as intermediates in this study), even though these compounds did not seem to dissolve completely in the aqueous solutions tested. This activity may be due to the slow hydrolysis of the bromo group to give the chlorophenoxy alkanols, which might in turn oxidize "in situo" (in the plant) to form 2,4-dichlorophenoxyacetic acid, 2,4-dichlorophenoxypropionic acid, etc. Further evaluation of these compounds is contemplated.

ACKNOWLEDGMENTS

The authors are grateful to the Research Corporation and the Denison Research Foundation for financial grants which supported this work. The authors also wish to express their gratitude to Dr. W. C. Boll of McGill University who carried out the plant growth tests in his laboratories with the assistance of one of the authors (H. Lee).

BIBLIOGRAPHY

1. M. H. Maguire and G. Shaw, *J. Chem. Soc.*, 1756 (1955).
2. M. H. Maguire and G. Shaw, *ibid*, 311 (1957).
3. G. M. Kosolapoff, *J. Am. Chem. Soc.* **70**, 1971 (1948).
4. W. J. Hickinbottom. "Reactions of Organic Compounds", Longmans, Green and Co., New York, N. Y. (1948), p. 91.
5. C. S. Marvel and A. L. Tanenbaum in "Organic Syntheses", Vol. IX, John Wiley and Sons, Inc., New York, N. Y. (1929), p. 72.
6. G. M. Kosolapoff, "Organophosphorus Compounds", John Wiley & Sons, Inc., New York, N. Y. (1950), p. 121.
7. L. J. Audus, "Plant Growth Substances", Leonard Hill Limited, London, England (1953), pp. 23-31.
8. A. C. Leopold, "Auxins and Plant Growth", University of California Press, Berkeley and Los Angeles, Calif. (1955), pp. 18-47.
9. Personal communication (to D. R. S.), dated February 4, 1955, from Dr. Frank A. Gilbert, Battelle Memorial Institute, Columbus, Ohio.

SOME PHYSIOLOGICAL CORRELATES OF PSYCHOLOGICAL STRESS IN THE ADRENAL ORGANS OF THE WHITE MOUSE[1]

LAURENCE ROBERT SIMSON, JR.[2]

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INTRODUCTION

Selye's work on the general-adaptation-syndrome is certainly of tremendous importance in winning some better understanding of the interaction between the "psychological" and the "somatic" aspects of organisms. His study of total systemic and specifically of adrenocortical responses to both specialized and specific stress situations is necessarily limited to stresses which are quantifiable and reproducible. But very often an organism will exhibit a syndrome from which one may infer only a non-reproducible and non-quantifiable stress situation. And it is here that Selye is subject to sharp criticism for extrapolating perhaps too much, for interpreting particular syndromes as being correlated with "psychological" stresses which may have the same physiological and anatomical

[1] Thesis of an honors project carried out in the Department of Biological Sciences, Denison University, in 1956–7.

[2] Class of 1957, Denison University.

consequences in the organism as such severe and measurable physical stresses as cold, electric shock, chemical stimulants, and so on.

This study was undertaken in an attempt partially to bridge this gap between "psychological" and "somatic" factors. These distinctions seem to be very artificial, carry-overs from an older philosophy that was grounded in a duality of "mind" and "body." Such a philosophy has never been able to account for interaction of mind-stuff and body-stuff, nor even to demonstrate the existence of the former. True, valiant attempts have been made by mathematicians and physiologists and metaphysicians, but they have all been unsuccessful. Now it seems most profitable to abandon these distinctions entirely, to try a new approach (though it is not in fact a new approach, for the antique Hebrews thought this way) of treating organisms as whole organisms, as living systems operating in an environmental field.

The words "psychological" and "somatic" must now be understood as convenient ways of talking about something analogous to our subjective "thinking-behavior" and the organic structure of the living organism. These aspects are mutually interdependent, and may even be thought of as on a continuum. We cannot say where body chemistry ends and "thinking" begins.

STATEMENT OF THE PROBLEM

If a stress situation is made as nearly "psychological" as possible, that is involving a minimum of physical trauma, is the general-adaptation-syndrome evoked?

(For purposes of this study it seemed most desirable to work with the fairly well understood changes in the size and histological structure of the adrenal cortex. If changes characteristic of the G.A.S. were observed in these tissues, it would substantiate the view that this syndrome could be evoked by "psychological" stress. See Appendix, p. 149, for a list of such changes.)

Secondarily, the experimenter undertook to study the spleens of the stressed animals with a view toward understanding the observed increase in splenic weight.*

PART ONE

Study of Changes in the Adrenal Cortex

I. THE GENERAL-ADAPTATION-SYNDROME

The general-adaptation-syndrome (G.A.S.) is the sum of all non-specific systemic reactions of the body which ensue upon long continued exposure to stress. This is distinct from specific adaptation reactions such as the development of muscle through usage, allergic and immunologic phenomena elicited by foreign

* Bevan, John Morgan: Effects of Stress Upon Certain Physiological Mechanisms and Behavior of the Albino Rat. Ph.D. Thesis, Duke University, 10-3-52. Bevan observed that the mean weights of various organs examined were identical except for the spleen. Spleens of animals exposed to a kind of "psychological" stress tended to be somewhat heavier than those of control animals.

proteins or microorganisms, et cetera. Both the manifestations of these adaptive reactions and the resistance which they confer upon the body are specific to the agents which elicited them.

When an organism is continuously exposed to stress of a certain type, the resulting G.A.S. evolves in three distinct stages: the "Alarm Reaction," the "Stage of Resistance," and the "Stage of Exhaustion." It is important to note here that the alarm reaction is to be understood as merely the first stage in the total G.A.S.

The alarm reaction is the sum of all non-specific systemic phenomena elicited by sudden exposure to stimuli to which the organism is quantitatively or qualitatively not adapted. Some phenomena are merely passive, and represent signs of damage or "shock." Others are signs of active defense against shock. Two more or less distinct phases may be evident in the alarm reaction: the phase of shock, and the phase of countershock. If the exposure to damage is not very sudden, or if the damaging agent to which the organism is exposed is relatively mild, countershock phenomena may become evident without signs of the preceding phase of actual "shock." Some investigators distinguish between "primary" and "secondary" shock, suggesting that the first, which is almost instantaneous, is due to nervous stimuli, and that "secondary" shock is correlated with intoxication with endogenous substances. The recent discovery of countershock may explain cases in which a distinct period of primary shock followed after an intermediate period of well-being. It is possible that in such cases the intermediate shock-free period is merely the equivalent of the countershock phase which later proves insufficient and gives way to fatal shock.

The stage of resistance represents the sum of all non-specific systemic reactions elicited by prolonged exposure to stimuli to which the organism has acquired adaptation as a result of prolonged exposure. This is characterized by increased resistance to the particular agent to which it is exposed and decreased resistance to other types of stress. So it would seem that adaptation to any one particular agent is acquired at the expense of resistance to other agents.

The stage of exhaustion represents the sum of all non-specific systemic reactions which ultimately develop as a result of very prolonged exposure to stimuli to which adaptation had been developed, but could no longer be maintained.

By specific resistance is meant the type of inurement which increases resistance only against the particular type of stress to which the body has been exposed. Conversely, non-specific resistance designates the ability of the body to withstand qualitatively different stress from that to which it was developed.

The term "adaptation energy" is used to describe the ability of the organism to acquire resistance to stress.

II. CHARACTERISTICS OF PHASES OF THE G.A.S.

Alarm Reaction

The organism responds with the same set of symptoms to a great variety of agents, which responses may be represented as the body's defense forces. The alarm reaction consists of two more or less distinct phases, although the transition is not clearly defined.

Shock Phase: Tachycardia, decrease in muscle tonus and body temperature, formation of gastric and intestinal ulcers, hemoconcentration, anuria, edema formation, decrease in blood chlorides, acidosis, transitory rise and following decrease in blood sugar, and discharge of adrenalin from the adrenal medulla. This phase may last from a few minutes to twenty-four hours, and unless fatal, is followed by the phase of countershock.

Countershock Phase: Characterized by changes in the adrenal cortex (which changes will be discussed in some detail), involution of the thymus and other lymphatic organs, and reversal of the characteristics of the shock phase.

Stage of Resistance

If treatment with the alarming stimulus continues, the countershock phase gradually merges into the stage of resistance, during which most of the morphologic lesions regress and specific resistance to eliciting stimuli reaches its peak.

Stage of Exhaustion

Finally, it has been found that even a perfectly adapted organism cannot indefinitely maintain itself in the stage of resistance. If exposure to abnormal conditions continues, adaptation wears out, and lesions characteristic of the alarm reaction reappear. From this develops the stage of exhaustion during which further resistance becomes impossible.

III. SUMMARY OF FUNCTIONS AND STRUCTURE OF ADRENAL ORGANS

Activity of Cortical Secretions

The active crystalline substances that have been recovered from the adrenal cortical tissue (to date about 30 in number) belong to a group of substances called "steroids." These all have a basic cyclopentanophenanthrene nucleus. These various steroids may be grouped into three types according to their physiologic activity:

1) The desoxycorticosterone-like group participates in the control of the sodium-potassium balance in the body. When the production of these hormones is prevented (a situation characterized in the Addison's-disease syndrome), sodium is lost from the body into the urine, and potassium accumulates in the blood.

2) A second group, the II-oxysteroids (e.g. cortisone), is less understood. These substances also seem to exert some influence on sodium retention and potassium secretion, but their most pronounced and distinctive effect is on protein and carbohydrate metabolism. Cortisone has a catabolic effect on protein and tends to stimulate its conversion to carbohydrate. Quite unlike insulin, cortisone causes glycogen to be laid down in liver tissue without lowering the blood-glucose level.

The catabolic effect of cortisone is also evident in lymphatic tissue. Administration of the hormone leads to a rapid reduction in the size of the thymus, the spleen, and other deposits of lymphatic tissue. There is some suggestion that large doses of cortisone may cause breakdown of lymphocytes. In still a further way, by causing a reduction in the rate of mitosis in lymphatic tissue, cortisone acts to reduce the size of these organs. Effects of cortisone on the quantity and

quality of intercellular material and its role in the production of eosinophilia will not be discussed here.

3) The third group of hormones manufactured by the adrenal cortex are of the sex variety. Under some circumstances the adrenal glands seem to be able to supplement the hormone production of the gonads.

Activity of Medullary Secretions

There seems to be two secretions of the adrenal medulla, these secretions being similar chemically, but differing somewhat in physiological effects. These are called epinephrine (adrenalin) and nor-epinephrine (nor-adrenalin).*

STRUCTURE OF THE ADRENAL ORGANS

Cortex

Two theories have been offered to account for there being three layers in the adrenal cortex:

First, the suggestion has been made that each of these three zones of the cortex specializes in the production of one of the three types of hormones derived from the cortex as a whole. According to this theory the cells of the zona glomerulosa produce the hormones that primarily affect the salt balance, the cells of the zona fasciculata, the hormones that affect protein and carbohydrate metabolism, and the cells of the zona reticularis, the sex hormones.

A second theory offers that the zona glomerulosa is a germinative layer, and that nearly all new cells that are produced in the adrenal cortex are produced by mitosis in that area. These cells would then be pushed into the zona fasciculata, which, according to this theory, would function as the hormone producing zone. Having filled their secretory usefulness, these cells would be further pushed into the zona reticularis, where they would degenerate and die.

Medulla

Only one type of secretory cell seems to be present in the adrenal medulla.†

IV. EXPERIMENTAL PROCEDURE

Materials

Animals: Young male albino mice of uniform size were used.

Diet: "Purina Dog Chow," 24% protein.‡

* For a survey discussion of these substances the reader is referred to: "Physiology of Fear and Anger," D. H. Funkenstein, *Sci. Am.*, May, 1955.

† A more detailed discussion of the histologic structure of the adrenals may be found in *Histology*, Arthur W. Ham, J. B. Lippincott Company, 1953, and in *Text-Book of Histology*, Bremer and Weatherford, The Blakiston Company, 1944. The development of these structures is described in *Human Embryology*, Bradley M. Patten, The Blakiston Company, 1953, and *Analysis of Development*, Willier, Weiss, and Hamburger, W. B. Saunders Company, 1955. A brief survey of comparative endocrinology may be found in *Chordate Anatomy*, Neal and Rand, The Blakiston Company, 1948.

‡ Dietary protein seems to exert a very great influence on the weight of the adrenal organs. For a discussion of these effects refer to: *On the Experimental Morphology of the Adrenal Cortex*, Selye, Hans, Charles C Thomas, Publisher, 1950.

Housing: Experimental and control animals were housed in separate large communal cages.

Disease: During the last week of the experiment several animals died of what seemed to be an infectious respiratory disease. Early symptoms were: ruffled fur, indicating a high body temperature, formation of crust-like material around protruding eyes, and catatonic-like behavior. All mice dying of this infection showed highly inflamed lungs. It is important to note that both control and experimental animals were infected, so that it would not seem that the induced G.A.S. was necessarily correlated with increased susceptibility to infection.

There was another important result of this infection of the mouse colony. Some animals seemingly unaffected were discovered to have empty gastrointestinal tracts. It would seem that sick mice stopped eating before any other symptoms were observed. This being the case, it was not possible to get an accurate live-weight of the animals to compare with weights of adrenals and spleens.

Dissection: Forty-four hours after the last trial the mice were sacrificed with chloroform, and the organs removed through a single mid-ventral incision.

Histologic Technique: All tissues were washed in physiological saline and placed in Bouin's fluid for forty-eight hours before being washed with alcohol. All sections were made at 10 microns from paraffin mounts, and were stained with Standard Alum-Haematoxylin and Eosin.

Adrenals: The right adrenal was used in every case. Before staining, these organs were oriented in the same plane as in the normal mouse, then sectioned latero-mesiad (sagittally). The longest section from anterior to posterior was in each case the one studied. One adrenal from each group was sectioned anteroposteriorally (transversely). Again the criterion for choice of sections was their greatest cross-sectional length.

Determination of Relative Cross-Sectional Area of Cortex and Medulla: The same sections as were studied above were projected through a micro-projector on to graph paper ruled to 1 mm. squares. Outlines of cortex and medulla were traced, and the numbers of squares covered by cortex and medulla were determined by direct counting. These numbers were expressed as the ratio of medulla to cortex.

Apparatus and Technique: As we have seen, it was necessary to induce "stress" with a minimum of physical trauma. A conflict situation similar in type to those used to produce experimental neurosis was necessary, but a conflict situation which would not require a great deal of time for the learning of possible responses.

The test animals were put into a situation allowing only two courses of action: one leading (A) to a mild electric shock, the other (B) to exposure to a bright light. In this second situation the animal had to maintain the posture of clinging to the sides of the trial box. It would be expected that this posture would be fatiguing. Note, too, that mice are considered to be negatively phototropic creatures.

This trial box was basically a tunnel 12″ x 1½″ x 1½″. Five 3⁄16″ copper rods provided a floor. These rods were insulated away from one another; alternate rods were connected in parallel to a transformer and an inductorium. Though an animal placed in this tunnel might have avoided being shocked by standing on

like-charged electrodes, this presented no difficulty in actual operation. At one end of the tunnel was a small cage-like box 1½" x 4" x 4" made of ¼" wire mesh. This box was arranged in such a way that its sides were aligned with the inner walls of the tunnel. Light from a No. 2 photoflood bulb 4 feet away was directed through this wire cage. The walls of the tunnel provided a shaded area above the electrodes.

During the first trial each mouse was placed in the tunnel about midway from either end and facing the blind end (away from the wire cage fastened over the grid). After the animal had been permitted to explore for about one minute, a small current was applied to the electrodes. (An appropriate current had been previously determined—one that the mice would try to avoid, but one which would not produce convulsions nor cause the animals to squeak.) This current was applied in an on-off fashion by the rapid tapping of a telegraph-key type switch. By climbing into the wire cage the animal was able to avoid being shocked. Thus the mouse could either remain in the shaded floor area while being subjected to a mild electric shock, or it could cling to the sides of the wire cage above the grids and in the glare of a very bright light. In this way the animals were forced to discriminate between two alternatives, both undesirable.

Trial periods were 10 minutes long. In each succeeding trial the mouse was introduced into the apparatus as described earlier; and usually it would at once leap into the wire cage. During this brief interval the grid was not charged. During the second and third trials a few mice did drop down to the grid briefly, but on being shocked they quickly returned to the cage. In all following trials the animals remained in the cage for the entire 10 minute interval. Mice were placed in the apparatus on alternate days for a period of five weeks. All trials were made shortly after dark and during the period of increasing rodent activity.

V. OBSERVATIONS

Behavior of Animals in Apparatus

Behavior in the stress situation seemed generally the same for all animals in this experiment. By the fourth or fifth trial the mice seemed to be very disturbed by being placed in the apparatus. They carried on a great deal of face-washing behavior, would squeak almost constantly, and would make seemingly frantic efforts to struggle out of the cage. Occasionally one would place a paw on an electrode, but would seldom touch a second rod. After the second week no animal ventured into the tunnel. The rate of activity in the trial apparatus, though not quantified, seemed to increase to the end of the second week, and then to remain at this high level; that is, a high level of activity alternated with moments of stationary face-washing behavior.

Behavior of Animals in Home Cage

Behavior of the experimental animals in their home cage was quite noticeably different from that of the control mice. General activity seemed much lower than that of the control animals. When a recently stressed mouse was returned to the communal cage it was very likely to attack the animals already present. This

behavior became apparent during the third week and continued until the conclusion of the experiment.

Observations at Dissection

All experimental animals showed a great deal of clotted blood in the lateral portions of the abdominal cavity. Internal bleeding was not evident in the control mice. This bleeding seemed to have originated in the vessels of the mesentery proper; but this could not be determined with a certainty.

Measurements: Determination of the relative cross-sectional area of the cortex and medulla revealed the following:

Ratio of Cross Sectional Areas
Medulla to Cortex

Experimental Mice		Control Mice	
Number	Ratio	Number	Ratio
1	1:2.75	1	1:2.14
2	1:2.99	2	1:1.53
3	1:2.26	3	1:1.72
4	1:2.62	4	1:2.01
5	1:2.93	5	1:2.05
6*	1:2.52	6*	1:1.96
Average	1:2.68	Average............	1:1.90

* Tranverse sections.

While the original plan was to have 15 animals in each group the outbreak of disease in the colony made it necessary to reduce the number to 10. Finally only six animals in each group were studied with respect to their adrenal organs.

*Histology:** These experimental mice seemed to exhibit both adrenal hypertrophy and hyperplasia. This worker observed no other structural changes such as hemorrhagic infarction or myeloid metaplasia, nor did he see evidence of any lipid granule storage of discharge. But it must be remembered that a more skillful observer, and one using special staining techniques for the detection of lipids, hyalin, fibrin, and so forth, might have observed evidence of some of these adrenal responses.

VI. CONCLUSIONS

Factors to be Considered: Accessory Adrenal Tissue

In mammalian embryology the adrenal cortex arises from the mesoderm in the urogenital zones. Small rests of adrenal glandular cells (called accessory cortical tissue, or cortical rests) may also often be found outside the adrenal capsule in the region of the kidneys or gonads (when associated with the gonads

* In studying the histologic material this experimenter used as his guide Selye's discussion of the morphology of rat adrenals found in his report: "On the Experimental Morphology of the Adrenal Cortex", Charles C Thomas Company, 1950.

they are called accessory adrenals of Marchand). The medullary tissue, on the other hand, develops from the neural crest, and remains intimately connected with the splanchnic sympathetic nerve supply. Tissue similar to that of the adrenal medulla, called chromaffin tissue, may appear in various places retroperitoneally along the course of the aorta, in the region of the abdominal sympathetic plexus, and near the roof of the inferior mesenteric artery (aorticchromaffin body, lumbar paraganglionic mass, organs of Zuckerkandl).

Such irregular appearance of accessory adrenal tissue greatly complicates experimental work depending on complete removal or accurate measurement of the adrenals. These small portions of tissue can be found only through extremely careful dissection and staining techniques. Such procedures were far beyond the scope of this work. Therefore, there is injected into this experiment a degree of uncertainty correlated with individual variations of the animals and with the relative importance of the roles played by these accessory organs. It is felt by this experimenter that the error introduced at this point is considerably less than the over-all "experimental error" implicit in this study.

Effect of Electric Shock

Some participation of neuro-endocrine mechanisms in electro-shock is suspected. Recent observations have led to the conclusion that electro-convulsive therapy causes activation of the adrenal cortex similar to that seen in the G.A.S. But it should be pointed out again that the animals used in this experiment were subjected to electro-shock far below the level necessary to induce convulsions. This shock was over a short interval, and only during the first several trials for each animal. While the use of electro-shock must be considered as introducing a factor other than a "psychological" one, this factor is also very probably of little significance in this experiment.

Fatigue

Extremes of physical exhaustion constitute stresses which will evoke the G.A.S. These experimental mice were exposed to muscle fatigue while clinging to the sides of the test apparatus. Since these trial periods were only 10 minutes per day, on alternate days, and since caged mice normally carry on much clinging behavior without exhibiting overt signs of fatigue, the fatigue factor in this work does not seem significant.

Conclusion of Part One

The problem was to induce in mice the general-adaptation-syndrome, using as the stressor a situation described as "psychological." Relative increase in the size of the adrenal cortex with respect to the adrenal medulla was taken as evidence of adrenocortical hypertrophy and/or hyperplasia which are characteristic of this syndrome. As will be seen in PART TWO of this paper, study of the spleen gave further evidence to substantiate the view that psychologically stressed mice had developed the G.A.S. More specifically, when sacrificed these mice were probably in the last part of the stage of resistance, or entering the stage of exhaustion.

One conclusion may be drawn at this point: It seems very probable that "psychological stress" may induce the general-adaptation-syndrome in the laboratory mouse.

PART TWO

Study of Changes in Splenic Tissue

I. PROCEDURE

Histologic Technique: General preparation was the same as for adrenal tissue (Part I). The spleens were sectioned along their greatest dimension, and several sections from border to midline were studied. Splenic tissue from 10 animals in each group was examined.

II. OBSERVATIONS

Histology: Spleens of experimental animals were congested with blood, far more than appeared in the controls. This experimenter was not able to establish exactly the relative abundance of phagocytosed material in the splenic reticulo-endothelial system, nor the degree of lymphatic involution. Stressed animals showed a great increase in the numbers of megakaryocytes within the splenic tissue.*

III. CONCLUSIONS

Splenic Weight: It must be remembered that no attempt was made to determine the weights of the spleens of these experimental animals. That an increase in weight was to be expected was inferred from Bevan's observations of rats. By what means may this increase in splenic weight have occurred?

Selye points out that during the course of the typical alarm-reaction the spleen, as well as all other lymphatic tissue, undergoes involution. This degeneration tends to begin in the germinal centers of the malpighian follicles, and generally the white pulp is much more seriously affected than the red. Since this involution of the spleen is relatively slow, there is less tendency for edema fluid and nuclear debris to accumulate within the splenic tissue. Contraction of the splenic musculature further decreases the size of the organ and helps to discharge its reserve blood during the alarm-reaction.†

It has been noted that in acute infectious diseases in man that the spleen is usually enlarged. It would seem that while there is an involution of the lymphatic tissue generally, that the reticulo-endothelial cells are stimulated to increased phagocytic activity. It would seem, too, that exposure to stress causes splenic enlargement only if the organism is simultaneously flooded with some material which accumulates in the activated macrophages and thus increases

* Histology of megakaryocytes and other myeloid elements is discussed in the Histology texts cited in Part I.

† Although most of the pertinent work has been performed on rats, other species (e.g. cat, rabbit, guinea-pig) were shown to react in essentially the same manner. Selye, Hans: "The General-Adaptation-Syndrome and the Diseases of Adaptation," *The Journal of Clinical Endocrinology*, February, 1946.

their volume. The phagocytosed material over compensates for the usual loss of splenic tissue correlated with degeneration of lymphatic elements and the discharge of stored blood.*

Bevan's observation of increased splenic weight in the rat would seem to be correlated with this over compensation mechanism. As noted, this experimenter observed that the spleens of the experimental mice were engorged with blood, and were apparently not in a contracted condition. It seems probable that the clotted blood found in the abdominal cavity of these stressed mice could have supplied necrotic material to be phagocytosed by the reticulo-endothelial system of the spleen, and that the spleens of these animals would have showed enlargement associated with lymphoid degeneration and reticulo-endothelial swelling.

Splenic Megakaryocytes: Concerning the increase in the number of megakaryocytes: Unfortunately this study offers only a qualitative observation. Selye notes that in bone marrow undergoing intense atrophy induced by the alarm-reaction that megakaryocytes tend to persist.† It has also been observed that myeloid metaplasia involving the production of megakaryocytes occurs in the adrenal cortex of rats subjected to injections of necrotic tissue.‡ We must note that megakaryocytes are normally present in the spleen of the adult mouse.

There are several possible interpretations of the apparent increase in numbers of megakaryocytes in the splenic tissue of these experimental mice.

I. The increase may be only an apparent one, correlated with atrophy of the surrounding lymphatic tissue and exposure of a greater number of megakaryocytes in the sectioned material. Since these large cells tend to persist in atrophying myeloid tissue, one might infer that they would also tend to resist degeneration in lymphoid tissue.

II. There may have occurred an in situ multiplication of the megakaryocytes normally present in the rodent spleen. However, no mitotic figures were observed in this material.

III. Myeloid metaplasia similar to that observed in the rat adrenal cortex may have taken place in the splenic tissue.

IV. There may have occurred a migration of megakaryocytes from other myeloid tissue. It is conceivable that if extensive myeloid degeneration were occurring in the bone marrow, that megakaryocytes may have been swept into the circulatory system and been carried to the splenic tissue where they were entrapped. Examination of other lymphatic tissue would have been of great value in interpreting this finding.

COMMENTS

When we think of stress agents, we immediately think of such factors as cold, electric shock, chemical stimulants, and so on. That the general-adaptation-syndrome is evoked by these does not seem strange. But that the G.A.S. may

* Selye, Hans: *Stress, The Physiology and Pathology of Exposure to*, Aeta, 1950.

† Selye, Hans: *Stress*, 1950.

‡ Selye, Hans: *Experimental Morphology*, 1950.

be produced by something akin to experimental neurosis, something "psychological," something vague and hardly quantifiable, is indeed shocking! This is because we are accustomed to thinking of "somatic" aspects of organisms and "psychological" aspects of organisms. We seldom get the two together.

When we consider an organism in a stress situation, we must learn to consider a complex organic system interacting with a complex environmental field. We must consider the immediate physical situation, all previous interactions between organism and other environmental fields, the genetic make-up and peculiar body-chemistry of the specific organism, and, if we are able, its "thinking behavior".

Both severe physical trauma and severe psychological trauma may be understood as manifestations of an unbalanced condition between organism and environment. That the organism exhibits the same total systemic reactions (G.A.S.) to this unbalanced situation is not surprising. There is then no problem of "psychological" and "somatic" aspects of organisms, for these terms are understood to be merely convenient labels to denote extremes of organism-environment interdependence.

SUMMARY

Psychological stress was used to induce the general-adaptation-syndrome in a group of laboratory mice. These animals exhibited adrenocortical hypertrophy and hyperplasia, and an increase in the size of the adrenal cortex with respect to the medulla.

The spleens of these stressed animals were noted to be engorged with blood. Large numbers of megakaryocytes were in evidence in these tissues.

ACKNOWLEDGMENTS

For their help in the formulation and execution of this work I would like to extend my sincere appreciation to Dr. George D. Morgan, Dr. Arthur W. Lindsey, and Dr. Irvin S. Wolf. And for her very willing and able assistance in the laboratory I thank Miss Charlotte P. Bidwell.

APPENDIX

HISTOLOGICAL CHANGES WHICH HAVE BEEN OBSERVED IN THE ADRENAL ORGANS OF ANIMALS IN VARIOUS STAGES OF THE G.A.S.*

1. Atrophy
2. Hypertrophy
3. Hyperplasia
4. Capsular adenomas
5. Lipid granule storage or discharge
6. Cholesterol granule storage or discharge
7. Plasmal granule storage or discharge
8. Ascorbic acid granule storage or discharge

* This list is taken from: *On the Experimental Morphology of the Adrenal Cortex*, Selye, 1950.

9. Fatty metaplasia
10. Colloid formation
11. Fibrinoid degeneration
12. Cytolysis
13. "Chromidiosis"
14. Lymphoid and myeloid metaplasia
15. Formation of lumina with cortical parenchyma
16. Holocrine secretion
17. Hyperemia
18. Hemorrhage infarction
19. Focal necrosis
20. "Toxic involution"

BIBLIOGRAPHY

BOOKS

Beach, Frank A. *Hormones and Behavior:* Harper and Brothers, 1949

Bremer, John Lewis and Weatherford, H. L. *A Textbook of Histology:* The Blakiston Company, 1944

Farris, Edmond J. *The Rat in Laboratory Investigation:* J. B. Lippincott Company, 1949

Fulton, John F. *A Textbook of Physiology:* W. B. Saunders Company, 1955

Gero, Alexander. *Biological Chemistry:* The Blakiston Company, 1950

Gray, Henry. *Anatomy of the Human Body*, 26th Edition: Lea and Febiger Company, 1954

Ham, Arthur W. *Histology:* J. B. Lippincott Company, 1953

Helson, Harry (Editor). *Theoretical Foundations of Psychology:* D. Van Nostrand Company, 1951

Hoskins, Roy G. *Endocrinology, The Glands and Their Functions:* W. W. Norton and Company, 1950

Nordenskiold, Erik. *The History of Biology:* Tudor Publishing Company, 1928

Odum, Eugene P. *Fundamentals of Ecology:* W. B. Saunders Company, 1953

Patten, Bradley M. *Human Embryology:* The Blakiston Company, 1953

Selye, Hans. *On the Experimental Morphology of the Adrenal Cortex:* Charles Thomas Company, 1950

Selye, Hans. *Stress, The Physiology and Pathology of Exposure to:* Aeta, 1950

White, Handler, Smith and Stetten. *Principles of Biochemistry:* McGraw-Hill Company, 1954

PAPERS AND PERIODICAL ARTICLES

Bevan, John Morgan. "Effects of Stress upon Certain Physiological Mechanisms and Behavior of the Albino Rat": *Ph.D. Thesis*, Duke University, October 3, 1952

Beard, Persky and Hamburg. "Psychological Stress and Endocrine Function": *Digest of Neurology and Psychiatry*, September, 1956

Dixon, Wallace C. "Comparative Morphology of the Adrenal Glands of Wild and Domestic Mice and the Effect of Captivity on Adrenal Structure": Abstract of a *Dissertation*, Boston University, 1956

Finger, Frank W. "Convulsive Behavior in the Rat": *Psychological Bulletin*, May, 1947

Selye, Hans. "The General-Adaptation-Syndrome and the Diseases of Adaptation": *The Journal of Clinical Endocrinology*, February, 1946

Selye, Hans. "Stress and Disease": *Science*, October, 1955

Shaklee and Ornat. "Endocrine and Behavioral Effects of Intensive Schedules of Electroconvulsive Shock": *The Journal of Psychology*, October, 1956

Streb, Jack M. "Prefrontal Lobotomy and Anxiety Reduction in the White Rat": *Journal of the Scientific Laboratories*, Denison University, Vol. 43, Art. 7, 1954

A STUDY OF SIX DIFFERENT POND STOCKING RATIOS OF LARGEMOUTH BASS, MICROPTERUS SALMOIDES (LACÉPÈDE), AND BLUEGILL, LEPOMIS MACROCHIRUS RAFINESQUE; AND THE RELATION OF THE CHEMICAL, PHYSICAL AND BIOLOGICAL DATA TO POND BALANCE AND PRODUCTIVITY

GEORGE D. MORGAN[1]

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Figures

Tables

INTRODUCTION

This paper is the result of a five year project on stocking ratios of largemouth bass and bluegills in twelve one acre ponds at the U. S. Fish Hatchery located at Hebron, Ohio. The project was set up as a joint program by the U. S. Fish and Wildlife Service, and the State of Ohio Department of Natural Resources, Division of Wildlife.

The project was under the supervision of the author, Professor of Biology at Denison University, Granville, Ohio. The collecting and the analysis of most of the data were done by the author and his co-workers, David E. Morgan and Robert Cash, both students at Denison University. The original stocking of the ponds was carried out by Mr. Paul Handwerk, Fisheries Biologist of the U. S. Fish and Wildlife Service, with the help of Mr. Verle Crandell, Superintendent of the hatchery and his assistants, Messrs. Charles Oldham, George Griffith, and Jack Brennan. The ponds were drained at the end of the experiment by Mr. Paul Handwerk and Mr. Lyle Pettijohn, also of the U. S. Fish and Wildlife Service. At this time the fish were counted, measured, weighed and fish samples and scale samples were collected and turned over to the author for analysis.

I am deeply grateful to all of these co-workers for their help in the field and to the Supervisors of the U. S. Fish and Wildlife Service and the State of Ohio Department of Natural Resources for setting up the experimental ratios and for making the project possible.

The objectives of the project were:

1. The establishment of practical methods for stocking farm ponds, taking into consideration the number, size, species, species combinations and the time of the year.
2. To train personnel in farm pond management.
3. To furnish information and to demonstrate correct farm pond management to County Farm Agents, to soil Conservation Service Personnel, to small pond owners and other interested people.

PROCEDURES

Twelve one acre ponds were made available by the U. S. Fish and Wildlife Service at their Fish Hatchery located at Hebron, Ohio. The ponds are rectangular in form with sloping banks wide enough for trucks to travel between the ponds. They vary in depth from two feet at the shallow end to five feet at the deeper end. Figure 3 is an aerial photograph of most of the hatchery ponds. Those that were used in this experiment are marked C3, C4 etc. The ponds are supplied with water from Buckeye Lake over a part of the old canal system which is located across the road from the hatchery. The water is piped to each individual pond, and each pond has its own draining system which empties into a branch of the Licking River which flows through the hatchery. The stocking ratios were as follows (Table 1).

Data on the project were collected daily and weekly throughout the year as

TABLE 1

Ponds	Stocking Dates	Fish	Number	Size in Inches
C3 and C5	7/18/53	Largemouth bass	200	2–2⅛
	9/4/53	Bluegills	1000	2–2⅛
C4 and C6	7/28/53	Largemouth bass	100	2–2⅛
	9/17/53	Bluegills	1000	2–2⅛
C7 and C9	7/7/53	Largemouth bass	100	2–2⅛
Kentucky ratio	11/11/52	Bluegills	30	Adult breeders
C8 and B9	9/23/53	Largemouth bass	100	2–2½
Illinois ratio	11/9/53	Bluegills	100	2⅛–2½
B4 and B7	8/26/53	Largemouth bass	200	2⅛
Indiana ratio	9/4/53	Bluegills	200	1⅞–2⅜
B5 and B8	9/22/53	Largemouth bass	100	2¼–3
	9/22/53	Bluegills	1000	2–2⅜

time and weather permitted. The data included the *p*H, air and water temperature, the dissolved oxygen, carbon dioxide, carbonates, bicarbonates, total alkalinity, number and kinds of zooplankters, and growth and reproduction. Zooplankton was collected with a standard plankton net, number 12 mesh. Collections were made biweekly throughout the year as weather permitted. A number 800 Sedgwick Rafter counting chamber was used in determining the number of zooplankters per liter. Populations and reproduction were determined during the summer by seining. Harvestable bluegills were caught in hoop nets stretched across the pond. Harvestable bass were caught by angling. Yearly growth and annual increment were determined from the reading of the annuli on the scales, with the aid of a rayoscope.

BALANCED AND UNBALANCED PONDS

According to the findings of H. S. Swingle and E. V. Smith (1950), pond balance can be determined through seining at intervals during the summer months. When seining records show that bass reproduction had occurred and that bluegill reproduction had taken place during early, middle and late summer the ponds are considered to be in balance.

During 1954, Table 2, the seining record of all ponds showed that bass reproduction had occurred only in ponds C7 and C9, the Kentucky ratio. These ponds were stocked with 30 breeder bluegills in the fall of 1952 and with bass two inches in length in July of 1953. All other ponds were stocked in 1953 with both bass and bluegills two inches in length and in different ratios and on different dates, Table 1. Bass in C7 and C9 grew 9.1 and 8.8 inches in one year as compared with 6.29 inches, the greatest growth realized in all the other ponds, Table 7. The failure of the bass to reach normal spawning length (9 inches) in all

TABLE 2

Summary of Reproduction from the Seining Record During 1953, 1954, 1955 and 1956, and from the Scale Record from Fishes Recovered by Draining the Ponds in 1956

Record of Reproduction from Seining																	
Bass		1953		1954				1955				1956				Same as the scale record	Pond Balance
		Bluegills			Bluegills				Bluegills				Bluegills				
Pond	Stocked	Stocked		Bass	Early	Middle	Late	Bass	Early	Middle	Late	Bass	Early	Middle	Late		
C3	7/18/53	9/4/53		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	†
C5	7/18/53	9/4/53		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	†
C4	7/28/53	9/17/53		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	†
C6	7/28/53	9/17/53		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	†
C7	7/7/53	Adults	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	†
C9	7/7/53	11/11/52	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	*
C8	9/23/53	11/9/53		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	*
B9	9/23/53	11/9/53		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	*
B4	8/26/53	9/4/53		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	†
B7	8/26/53	9/4/53		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	†
B5	9/22/53	9/22/53		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	†
B8	9/22/53	9/22/53		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	†

Summary of Reproduction Derived from a Study of the Scale Annuli from Fishes Recovered by Draining the Ponds

Reproduction																	
Bass		1953		1954				1955				1956				Same as the scale record	Pond Balance
		Bluegills			Bluegills				Bluegills				Bluegills				
Pond	Stocked	Stocked		Bass	Early	Middle	Late	Bass	Early	Middle	Late	Bass	Early	Middle	Late		
C3	7/18/53	9/4/53		No	?	Yes	?	Yes	?	Yes	?	Yes	Yes	Yes	Yes	No	†
C5	7/18/53	9/4/53		No	?	Yes	?	Yes	?	Yes	?	Yes	Yes	Yes	Yes	No	†
C4	7/28/53	9/17/53		No	?	Yes	?	No	?	Yes	?	Yes	Yes	Yes	Yes	No	†
C6	7/28/53	9/17/53		No	?	Yes	?	Yes	?	Yes	?	No	Yes	Yes	Yes	Yes	†
C7	7/7/53	Adults	Yes	Yes	?	Yes	?	Yes	?	Yes	?	Yes	Yes	Yes	Yes	No	†
C9	7/7/53	11/11/52	Yes	Yes	?	Yes	?	Yes	?	Yes	?	Yes	Yes	Yes	Yes	No	*
C8	9/23/53	11/9/53		No	?	Yes	?	Yes	?	Yes	?	Yes	Yes	No	No	No	*
B9	9/23/53	11/9/53		No	?	Yes	?	Yes	?	Yes	?	Yes	Yes	No	No	Yes	*
B4	8/26/53	9/4/53		No	?	Yes	?	Yes	?	Yes	?	Yes	Yes	Yes	Yes	Yes	†
B7	8/26/53	9/4/53		No	?	Yes	?	Yes	?	Yes	?	Yes	No	Yes	Yes	Yes	†
B5	9/22/53	9/22/53		No	?	Yes	?	Yes	?	Yes	?	Yes	Yes	Yes	Yes	No	†
B8	9/22/53	9/22/53		No	?	Yes	?	Yes	?	Yes	?	Yes	Yes	Yes	Yes	No	†

† Balanced ponds.
* Unbalanced ponds.

but C7 and C9 may have been due to a lack of food. The breeder bluegills in C7 and C9 spawned in 1953 so that there was plenty of small forage fishes present for the small bass to feed upon. Pond balance was not considered during 1954 since the bass in most of the ponds had not yet reproduced.

During 1955 the seining record showed that bass reproduction had taken place in all ponds. Also, bluegill reproduction had taken place during early, middle and late summer. Therefore all of the ponds were considered to be in balance. However, according to the draining record in 1957, Table 2, there was no bass reproduction in C4 during 1955, since no bass of the 1955 class were present and a study of the scale annuli showed no bass with two annuli, Table 17. However, since the seining record showed that bass reproduction had taken place in 1955 in pond C4 it is assumed that the reproduction must have been very light and that the young fry were eaten by the older bass.

During 1956 the seining record showed that only pond B4 was in balance. During this year this pond had bass reproduction, and early, middle and late bluegill reproduction, Table 2. However, according to the draining record and the scale annuli record only C6 had no bass reproduction in 1956. The smallest bass recovered from this pond in 1957 were 5.5 inches in length, which, according to the scale record, belonged to the 1955 class, Table 17. Contrary to the seining record bass reproduction did occur in C7. Bass between 4.5 and 5.0 inches in length were recovered from this pond and the scale record showed that they belonged to the 1956 class, no annulus being present, Table 12.

Seining in 1956 to determine early, middle and late bluegill reproduction was only 41 % accurate. The seining and draining records were the same in five ponds only. The records did not coincide in seven of the ponds, Table 2. Therefore in this work seining records alone were not a good indication as to whether the ponds were in balance or unbalanced. This may have been due to a failure of securing a good representative sample because of an excessive growth of submerged vegetation in some ponds.

POND BALANCE AS DETERMINED THROUGH DRAINING THE PONDS IN 1957

A balanced population as defined by H. S. Swingle (1950) is characterized by the following characteristics:

(1) A definite range in the ratio (F/C) of the weight of all forage fishes to the weight of all piscivorous fishes. This range in a balanced population is 1.4 to 10.0. The desirable F/C range is 3.0 to 6.0.

(2) A narrow range in the ratio (Y/C) of the weight of all small forage fishes to the total weight of the piscivorous fishes. The Y/C in a balanced pond is 0.02 to 5.0. The desirable range is 1.0 to 3.0.

(3) An A_T value, or the total weight of a population composed of fishes of harvestable size. In balanced populations the range is from 33 to 90. The most desirable range is from 60 to 85. Values in excess of 85 indicate overcrowding with carnivorous species.

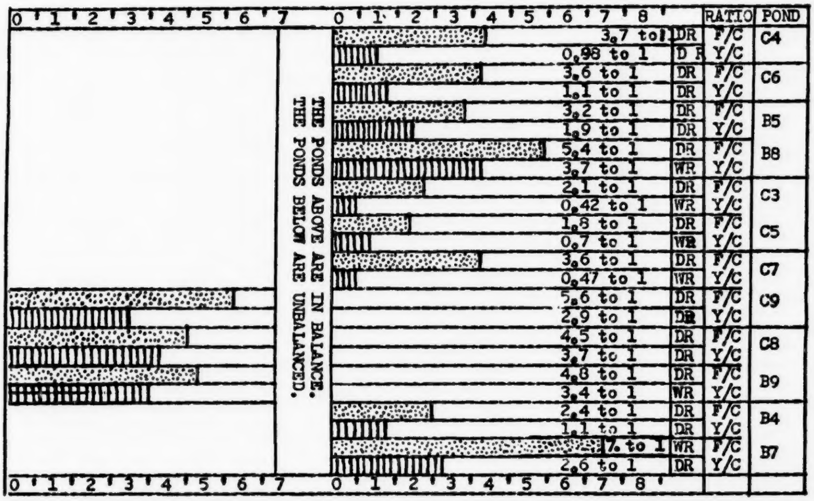

FIG. 1. The F/C ratio, total weight of all forage fishes to the total weight of all piscivorous fishes, and the Y/C ratio, total weight of all small forage fishes to the total weight of all piscivorous fishes in nine balanced and three unbalanced one acre ponds. Note that both the F/C and Y/C ratios in the three unbalanced ponds are within the balanced ranges of F/C 1.4 to 10, and Y/C 0.02 to 5.0. DR. = Desired range. WR. = Within the range.

(4) An A_F value, or total weight of the forage class composed of large fishes. The A_F value in balanced ponds is from 18.2 to 99.6. The most desirable range is from 60 to 80. Values above 85 occur only in populations overcrowded with piscivorous species. An A_F range of 35 is the minimum value found in desirable populations.

(5) An I_F value, or total weight of forage fishes composed of intermediate sizes. The I_F range in unbalanced ponds is between 0 and 100.0. The range in both balanced and unbalanced ponds overlap.

(6) An S_F value, or total weight of forage fishes composed of small sizes. The values in a balanced population range between 0.4 and 80.9. Satisfactory population occurred in a range of 15 to 40. Values in excess of 60 indicated inefficient populations.

When based on the above characteristics all ponds with the exception of C9, C8, and B9 were in balance, Figures 1, 2, and Table 3. Tables 34 to 39 inclusive show the kinds of fishes, pounds of each species, pond balance and the ranges of F/C, Y/C, A_T, A_F, I_F and S_F for each pond.

When based on the nearest to the mean of the desired ratios of F/C and Y/C, and the percentage of A_T, A_F, I_F, and S_F the ponds fall into the following order of first to last, Table 4.

Note that of the nine balanced ponds the seven best ratios were those in which the bass were stocked in the summer, and the bluegills in the fall. Pond C7 is an

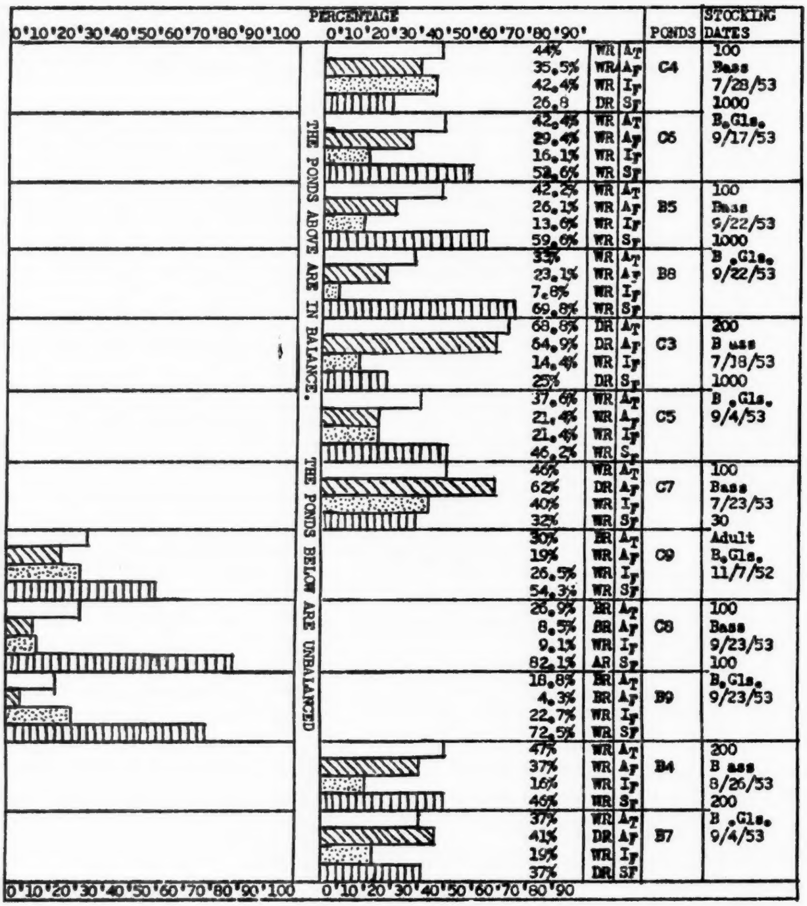

FIG. 2. Percentages of A_T, A_F, I_F, and S_F in nine balanced and three unbalanced one acre ponds stocked with six different ratios of bass and bluegills.

Balanced Populations (Swingle 1950)

Ratio	Range	Desired Range	Range	Desired Range
F/C	1.4 -10.0	3.0-6.0	A_T 33% to 90%	65% to 80%
Y/C	0.02- 5.0	1.0-3.0	A_F 18.2% to 99.6%	60% to 80%
			S_F 0.4% to 86.9%. Above 60% are considered inefficient populations. Desired range 15 to 40.	
			I_F In the test ponds the percentages overlapped in both balanced and unbalanced ponds. The range balanced ponds was between 0 and 41.4. In unbalanced ponds the range was between 0 and 100%.	

F/C = Ratio of weight of all forage fishes to the weight of piscivorous fishes.
Y/C = Ratio of weight of all small forage fishes to the total weight of all piscivorous fishes.
A_T = Percentage of the total weight of the fish population composed of harvestable bass 10 inches and above, and forage fishes 5 inches and above.
A_F = Percentage of total weight of forage fishes composed of harvestable forage fishes 5 inches and above in length.
S_F = Percentage of total weight of forage fishes composed of small forage fishes from 7/8 of an inch to 3 inches in length.
I_F = Percentage of total weight of forage fishes composed of intermediate forage fishes between 3 and 5 inches in length.
WR. = Within the range. DR. = Desired range. AB. = Above the range. BR. = Below the range.

TABLE 3

The F/C, Y/C, A_T, A_F, I_F, and S_F Values, Total Pounds of Harvestable Fishes, and Total Pounds of All Fishes Recovered by Draining 12 One Acre Ponds April 1 to May 15, 1957

Ponds	Stocking Ratios of Bass and Bluegills	Total Pounds of Harvestable Fishes	Total Pounds of Fishes per Acre	D.R. F/C	D.R. Y/C	W.R. Y/C	D.R. A_T	W.R. A_T	A.R. A_T	B.R. A_T	D.R. A_F	W.R. A_F	A.R. A_F	B.R. A_F	D.R. I_F	W.R. I_F	D.R. S_F	W.R. S_F	W.R. S_F
							%	%		%	%	%		%		%	%	%	%
C4	100 Bass 7/28/53	131.7	302.75	3.7-1	.98-1			44				30.5				42.4	26.8		
C6	1000 B. Gls. 9/17/53	98.35	208.75	3.6-1	1.1-1			42				29.4				16.1		53.6	
	Total lbs.	230.05	515.5																
B5	100 Bass 9/22/53	101.35	204.05	3.2-1	1.9-1			42.2				26.1				13.6		59.6	
B8	1000 B. Gls. 9/22/53	70.7	214.0	5.4-1	3.7-1			33.0				23.1				7.8			68.9†
	Total lbs	172.05	418.05																
C3	200 Bass 7/18/53	198.2	292.5	2.1-1	.42-1		69.8				64.9					14.4		25	
C5	1000 B. Gls. 9/4/53	118.5	298.7	1.8-1		.7-1		37.6				21.4				21.4		46.2	
	Total lbs	316.7	591.2																
C7	100 Bass 7/7/53	100.4	278.35	3.6-1	.47-1			46			62					40		32	
C9*	30 Adult Bluegills 11/11/52	62.2	245.7	5.6-1	2.9-1					30*		19				26.5		54.3	
	Total lbs.	162.6	524.05																
C8*	100 Bass 9/23/53	111.8	451.05	4.5-1	3.7-1					26.9*				8.5*		9.1			82.1†
B9*	100 B Gls. 11/9/53	75.0	276.75	4.8-1	3.4-1					18.8*				4.3*		22.7			72.5†
	Total lbs.	186.8	727.85																
B4	200 Bass 8/26/53	86.5	180.0	2.4-1	1.1-1			47				37				16		46	
B7	200 B. Gls. 9/4/53	95.3	257.0	7.1-1	2.6-1			37			41					19	37		
	Total lbs.	181.8	437 0																

* = Unbalanced value.
† = Balanced value but inefficient.
D.R. = Desired range in balanced pond.
W.R. = Within the range in balanced ponds.
A.R. = Above the range, pond unbalanced.
B.R. = Below the range, pond unbalanced.
F/C. = Ratio of the weight of all forage fishes to the weight of all piscivorous fishes.
Y/C. = Ratio of the weight of all small forage fishes to the total weight of all piscivorous fishes.
A_T. = Percentage of the total weight of the fish population composed of harvestable bass 10 inches and above and forage fish 5 inches and above.
A_F. = Percentage of total weight of forage fishes composed of harvestable forage fishes 5 inches and above.
S_F. = Percentage of total weight of forage fishes composed of small forage fishes 7/8 of an inch to 3 inches in length.
I_F. = Percentage of total weight of forage fishes composed of intermediate forage fishes between 3 and 5 inches in length.

TABLE 4

Most Desirable Ratios Based on Nearest to the Mean of the Desired F/C and Y/C and Percentage of A_T, A_F, I_F, and S_F

Most Desirable	Pond	Stocking Ratios and Dates of Stocking			
Balanced Ponds					
First	C3	200 Bass	7/18/53	1000 Bluegills	9/4/53
Second	B4	200 Bass	8/26/53	200 Bluegills	9/4/53
Third	C4	100 Bass	7/28/53	1000 Bluegills	9/17/53
Fourth	C6	100 Bass	7/28/53	1000 Bluegills	9/17/53
Fourth	C7	100 Bass	7/7/53	30 Bluegills	11/11/52
Fifth	B7	200 Bass	8/26/53	200 Bluegills	9/4/53
Sixth	C5	200 Bass	7/18/53	1000 Bluegills	9/4/53
Seventh	B5	100 Bass	9/22/53	1000 Bluegills	9/22/53
Eighth	B8	100 Bass	9/22/53	1000 Bluegills	9/22/53
Unbalanced Ponds					
Ninth	B9	100 Bass	9/23/53	100 Bluegills	11/9/53
Tenth	C9	100 Bass	7/7/53	30 Bluegills	11/11/52
Eleventh	C8	100 Bass	9/23/53	100 Bluegills	11/9/53

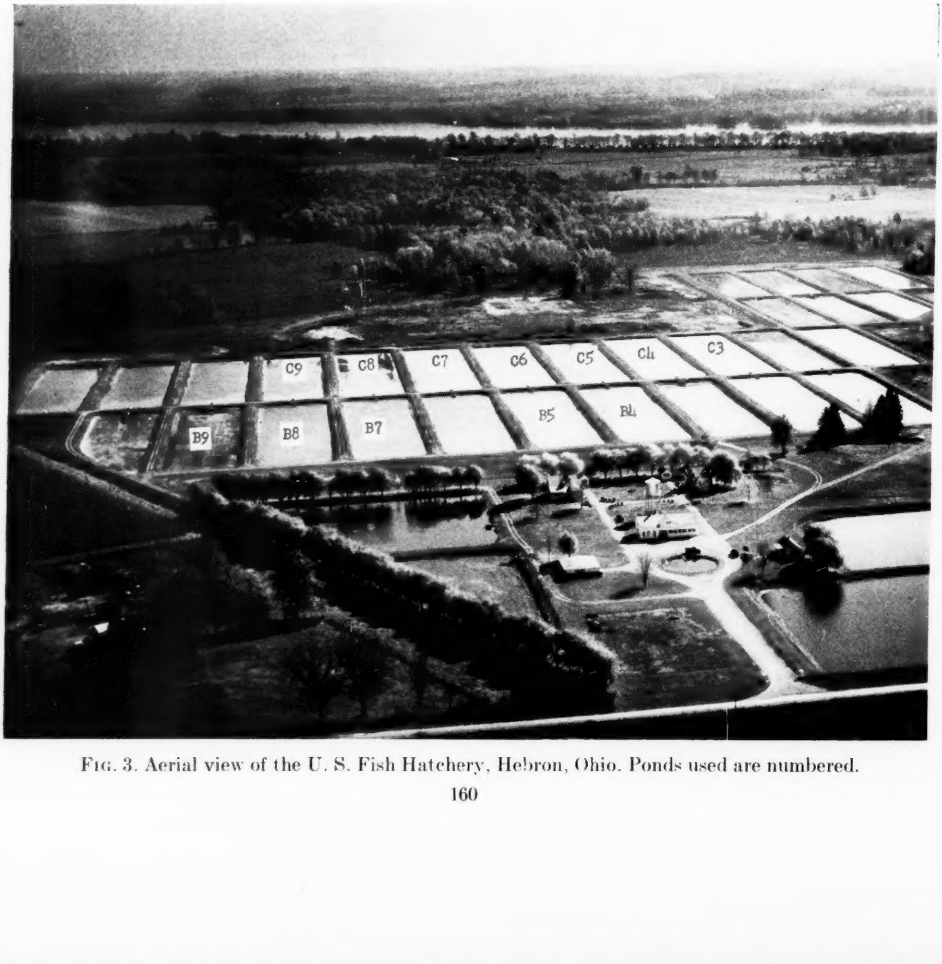

FIG. 3. Aerial view of the U. S. Fish Hatchery, Hebron, Ohio. Ponds used are numbered.

TABLE 5

Most Desirable Ratios Based on Balance and Pounds of all Harvestable Fishes Taken by Angling, Netting and by Draining of Ponds

Pond	Best Ratio	Actual Order	Pounds of Harvestable Fishes	Ratios and Stocking Dates			Pond Balance
C3	1st	1st	234.5	200 Bass	2″–2⅛	7/18/53	Balanced
C5		3rd	145.6	1000 Bluegills	2″–2⅛	9/4/53	Balanced
C4	2nd	2nd	169.8	100 Bass	2″–2⅛	7/8/53	Balanced
C6		5th	128.9	1000 Bluegills	2″–2⅛	9/17/53	Balanced
B4	3rd	9th	114.35	200 Bass	2⅛″	8/26/53	Balanced
B7		8th	126.1	200 Bluegills	1⅞–2⅜″	9/4/53	Balanced
B5	4th	6th	128.8	100 Bass	2¼–3″	9/22/53	Balanced
B8		11th	100.4	1000 Bluegills	2⅛″	9/22/53	Balanced
C7	5th	7th	128.7	100 Bass	2–2⅛″	7/7/53	Balanced
C9		10th	102.0	30 Adult Bluegills		11/11/52	Unbalanced
C8	6th	4th	139.05	100 Bass	2–2½″	9/23/53	Unbalanced
B9		12th	78.2	100 Bluegills	2⅛–2½″	11/9/53	Unbalanced

exception since it was stocked in the November of 1952 with adult bluegills, and fingerling bass in July, 1953.

The most desirable ratios are ponds C3 and B4 stocked with 200 bass and 1000 bluegills, and 200 bass and 200 bluegills respectively.

The least desirable of the balanced ponds were B5 and B8 stocked with 100 bass on 9/22/53, and 1000 bluegills on 9/22/53.

Both ponds stocked with 100 bass and 100 bluegills were unbalanced. Pond C9, stocked with the Kentucky ratio was unbalanced also.

If we consider the most desirable ponds in terms of both balance and pounds of harvestable fishes, the ponds fall into the order as shown in Table 5.

The best ratio in terms of balance and pounds of harvestable fishes by angling, netting and draining was the 200 bass and 1000 bluegills, ponds C3 and C5. These ponds rated first and third of the twelve ponds. The second most desirable ratio was the 100 bass and 1000 bluegills, ponds C4 and C6, stocked in July and bluegills in September. The least desirable ratio was 100 bass and 100 bluegills, C8 and B9. These ponds were stocked in the fall. Both of these ponds were unbalanced.

TOTAL POUNDS OF FISH TAKEN FROM EACH POND

Table 6 is a record of the total pounds of fishes produced in all the ponds including pounds recovered by angling and netting in 1956, and by draining the ponds in 1957.

It is interesting to note that the greatest poundage of fishes recovered was

TABLE 6

Total Pounds of Fishes Produced in 12 one Acre Ponds Including Pounds of Fishes Recovered During the Summer of 1956 by Netting and Angling, and Pounds of Fishes Recovered in 1957 by Draining the Ponds

Ponds	Stocking Ratios	Lbs. of Harvestable Large Mouth Bass Recovered by			Lbs. of Nonharvestable Bass Recovered by Draining in 1957	Total Pounds of L.M. Bass in Each Pond	Lbs. of Harvestable Forage Fishes Recovered by			Lbs. of Nonharvestable Forage Fishes in Each Pond 1957	Total Pounds of All Forage Fishes in Each Pond	Total Pounds of All Fishes in Each Pond 1956 and 1957
		Angling in 1956	Draining ponds 1957	Totals			Netting in 1956	Draining ponds 1957	Totals			
C4†	100 Bass 7/28/53	15.25	59.2	74.45	5.35	79.8	22.25	73.1	95.35	165.1	260.45	340.2
C6†	1000 B.Gls. 7/17/53	15.625	56.45	72.075	10.1	82.175	15.0	41.9	56.9	100.3	157.2	239.375
Total pounds for both ponds		30.875	115.65	146.525	15.45	161.975	37.25	115.0	152.25	265.4	417.65	579.575
B5†	100 Bass 9/22/53	15.625	53.55	69.175	3.5	72.675	12.0	47.8	59.8	135.2	195.0	267.675
B8†	1000 B.Gls. 9/22/53	15.25	30.7	45.95	2.65	48.6	12.7	41.75	54.45	138.9	193.35	241.95
Total pounds for both ponds		30.875	84.25	115.125	6.15	121.275	24.7	89.55	114.25	274.1	388.35	509.625
C3†	200 Bass 7/18/53	15.25	78.4	93.65	17.1	110.75	12.9	128.0	140.9	69.0	209.9	320.65
C5†	1000 B.Gls. 9/4/53	15.5	83.8	99.3	32.5	121.8	15.0	41.3	56.3	148.1	204.4	326.2
Total pounds for both ponds		30.75	162.2	192.95	49.6	232.55	27.9	169.3	197.2	217.1	414.3	646.85
C7†	100 Bass 7/7/53	15.375	61.2	76.575	10.0	86.575	13.5	38.7	52.2	168.45	220.65	307.225
C9*	30 Adult Bluegills 11/11/52	15.25	33.0	48.25	3.8	52.05	14.0	39.75	53.75	169.1	222.85	274.9
Total pounds for both ponds		30.625	94.2	124.825	13.8	138.625	27.5	78.45	105.95	337.05	443.5	582.125
C8*	100 Bass 9/23/53	16.25	80.0	96.25	1.3	97.55	11.0	31.8	42.8	338.35	381.15	478.70
B9*	100 B.Gls. 11/9/53	14.5	42.3	56.8	5.5	62.3	11.5	9.95	21.45	219.0	240.45	302.75
Total pounds for both ponds		30.75	122.3	153.05	6.8	159.85	22.5	41.75	64.25	557.35	621.6	781.45
B4†	200 Bass 8/26/53	15.25	39.2	54.45	12.9	67.35	12.6	47.3	59.9	80.6	140.5	207.85
B7†	200 B.Gls. 9/4/53	15.37	3.4	18.77	28.2	46.97	12.0	95.4	107.4	130.0	237.4	284.37
Total pounds for both ponds		30.62	42.6	73.22	41.1	114.32	24.6	142.7	167.3	210.6	377.9	492.22
Grand total		184.495	621.2	805.69	132.9	928.595	164.45	636.75	801.2	1861.6	2663.3	3591.845

† Balanced ponds.
* Unbalanced ponds.

478.7 pounds in C8 which is an unbalanced pond. However most of these fishes were small bluegills. The next best ponds in terms of total pounds were C4, C5, and C3. Pond C3 was the best balanced pond.

THE COEFFICIENT OF CONDITION (K VALUE) FOR LARGEMOUTH BASS

Table 7 gives the coefficient of condition for largemouth bass of different length classes, and the average K value for balanced and unbalanced ponds in each class. The K value is lowest in the smaller classes as would be expected. The K value becomes progressively greater as the fishes increase in length except

TABLE 7

Coefficient of Condition (K Value) of Largemouth Bass of Different Length Classes in 12 One Acre Ponds, Figures in Parentheses Represent the Number of Specimens Included

Ponds	Ratio	Standard Length in Inches														
		1.6–2.5	2.6–3.5	3.6–4.5	4.6–5.5	5.6–6.5	6.6–7.5	7.6–8.5	8.6–9.5	9.6–10.5	10.6–11.5	11.6–12.5	12.6–13.5	13.6–14.5	14.6–15.5	15.6–16.5
C4†	100 Bass and	(3) 1.93	(2) 1.91	—	—	—	—	(1) 2.20	(5) 2.36	(1) 2.09	—	(6) 2.36	(7) 2.01	(1) 1.76	—	—
C6†	1000 B.Gls.	—	—	—	(3) 2.84	(7) 2.08	(5) 2.16	(8) 2.14	(1) 2.29	(8) 2.06	(4) 2.13	(4) 2.18	(3) 2.10	—	—	—
B5†	100 Bass and	(2) 1.98	(4) 2.32	(1) 2.29	—	(3) 2.01	(4) 2.01	—	(2) 2.23	(1) 2.38	—	(3) 2.25	(5) 2.13	—	—	—
B8†	1000 B.Gls.	(2) 1.82	(4) 1.92	(1) 1.63	(3) 2.05	—	—	—	(1) 2.41	(5) 2.35	(7) 2.27	(4) 2.25	—	(1) 2.20	—	—
C3†	200 Bass and	—	(4) 1.87	—	—	(1) 2.03	(4) 2.07	(7) 2.12	(3) 2.13	(5) 2.07	(6) 2.25	(3) 2.22	(1) 2.18	—	—	—
C5†	1000 B.Gls.	—	(4) 2.06	(2) 2.41	—	(1) 2.03	(8) 2.11	(5) 2.52	—	(7) 2.34	(7) 2.14	(6) 2.17	—	—	—	—
C7†	100 Bass	—	—	(2) 1.79	(8) 1.89	(6) 2.06	—	(2) 1.85	(6) 2.20	(1) 2.27	(2) 2.19	(5) 2.35	(2) 2.68	(1) 2.49	(2) 2.40	(1) 2.71
C9*	30 Adult B.Gls.	(1) 1.98	(4) 1.71	—	(2) 1.89	(5) 1.68	(4) 1.97	(1) 1.78	—	(3) 1.99	(2) 2.24	(3) 2.09	(1) 1.36	(2) 2.31	—	—
C8*	100 Bass and	(3) 1.84	(1) 1.70	(2) 1.71	(5) 1.77	(2) 1.65	—	—	—	(1) 1.22	—	—	(3) 2.47	(5) 2.57	(1) 2.59	—
B9*	100 B.Gls.	(2) 1.64	(2) 2.00	(2) 2.13	(2) 2.18	(4) 1.96	(3) 2.10	(4) 2.28	(1) 2.10	(1) 1.68	(3) 2.35	(5) 2.37	(3) 2.34	—	—	—
B4†	200 Bass and	—	—	—	(3) 1.99	(3) 2.00	(5) 1.98	(4) 2.01	—	(7) 2.27	(8) 2.06	—	—	—	—	—
B7†	200 B.Gls.	(4) 1.75	(3) 1.67	—	—	(5) 1.91	(3) 1.99	(1) 2.00	(10) 1.63	(3) 1.86	(2) 1.84	—	—	(1) 2.68	—	—

A Comparison of the Average K Values of Largemouth Bass in all Balanced Ponds and in All Unbalanced Ponds

Balanced ponds	(11) 1.87	(21) 1.96	(6) 2.03	(17) 2.19	(26) 2.01	(29) 2.05	(28) 2.12	(28) 2.18	(38) 2.18	(36) 2.12	(31) 2.23	(18) 2.22	(4) 2.28	(2) 2.40	(1) 2.71
Unbalanced ponds	(6) 1.48	(7) 1.80	(5) 1.92	(9) 1.94	(11) 1.73	(7) 1.98	(5) 2.03	(1) 2.10	(5) 1.60	(5) 2.29	(8) 2.23	(7) 2.05	(7) 2.44	(1) 2.59	

† Balanced pond.
* Unbalanced pond.

TABLE 8

A Comparison of the Average K Values of Largemouth Bass of All Classes Combined in Each Pond

	Balanced Ponds									Unbalanced Ponds		
	C4	C6	B5	B8	C3	C5	C7	B4	B7	C9	C8	B9
Average K value......	2.08	2.22	2.17	2.11	2.11	2.22	2.23	2.05	1.91	1.89	1.94	2.09
	Average 2.12									Average 1.90		

TABLE 9

Relation of the Average K Value for All Classes in Each Pond for 1957 to the Average Number of Zooplankters per Liter for 1956

Largemouth Bass					Bluegills				
Pond	*K* value	Order	Zooplankters	Order	Pond	*K* value	Order	Zooplankters	Order
C7	2.23	1st	2,904.0	7th	C8*	3.46	1st	4,822.7	1st
C5	2.22	2nd	2,175.8	9th	C3	3.45	2nd	3,280.3	4th
C6	2.22	2nd	4,344.6	2nd	C4	3.17	3rd	3,493.8	3rd
B5	2.17	3rd	2,175.4	10th	C6	3.17	3rd	4,344.6	2nd
B8	2.11	4th	1,850.4	11th	C5	3.15	4th	2,175.7	9th
C3	2.11	4th	3,280.3	4th	B7	3.14	5th	2,612.6	8th
B9*	2.09	5th	2,982.2	5th	B9*	3.14	5th	2,982.2	5th
C4	2.08	6th	3,493.8	3rd	B8	3.13	6th	1,850.0	11th
B4	2.15	7th	1,519.4	12th	B4	2.97	7th	1,519.4	12th
C8*	1.94	8th	4,882.7	1st	C9*	2.88	8th	2,929.3	6th
B7	1.91	9th	2,612.6	8th	B5	2.77	9th	2,175.4	10th
C9*	1.89	10th	2,929.3	6th	C7	2.54	10th	2,904.0	7th

* Unbalanced ponds.

in a few cases. The lowest *K* value was in the 1.6 to 2.5 inches class. The greatest *K* value was 2.71 in the 15.6 to 16.15 inches class. It is interesting to note that the average *K* value for each class is higher in the balanced ponds with three exceptions, classes 10.6 to 11.5, 13.6 to 14.5 and 14.6 to 15.5, where the *K* value was higher in the unbalanced ponds.

Table 8 is a comparison of the average *K* value of all classes combined for each pond. Here again the *K* value is greater in the balanced ponds, the average being 2.12 as compared with 1.9 in the unbalanced ponds. Pond B7, although a balanced pond, had an undesirable number of intermediate bass in very poor condition, and only 3.4 pounds of harvestable bass. Also, this pond had 63 pounds of large carp and 3.5 pounds of gizzard shad. The turbidity of this pond was very high during 1955, being gaged between 1 ft. and 1 ft. 4 in. Also there was an excessive amount of submerged vegetation.

A comparison of the *K* value for 1957 and the average number of zooplankters per liter for 1956 shows no relation, Table 9. Note that pond C7 with a first for *K*

value is seventh in the average number of zooplankters per liter, while pond C8 is eighth for *K* value, and first in the number of zooplankters.

THE COEFFICIENT OF CONDITION (K VALUE) FOR BLUEGILLS

Table 10 gives the coefficient of condition of bluegills in all length classes, and the average *K* value for balanced and unbalanced ponds in each class. As in largemouth bass, the *K* value for bluegills becomes progressively greater as the fish grows. It is interesting to note that, with the exception of the ⅞″ to 1.5″ class, the *K* value for bluegills is greater than it is for largemouth bass. Also, as with bass, the average *K* value for bluegills, with two exceptions, is greater in the

TABLE 10

Coefficient of Condition (K Value) of Bluegills of Different Length Classes in 12 One Acre Ponds. Figures in Parentheses Represent the Number of Specimens in Each Class

Ponds	Ratio	Standard Length in Inches							
		⅞–1.5	1.6–2.5	2.6–3.5	3.6–4.5	4.6–5.5	5.6–6.5	6.6–7.5	7.6–8.5
C4†	100 Bass and	2.27 (1)	2.28 (4)	3.23 (7)	2.77 (3)	3.57 (7)	3.27 (4)	3.74 (2)	—
C6†	1000 B.Gls.	1.90 (3)	2.49 (5)	3.15 (3)	3.11 (8)	3.28 (2)	3.98 (8)	4.28 (1)	—
B5†	100 Bass and	1.64 (1)	2.34 (5)	2.07 (4)	2.80 (4)	3.32 (5)	3.53 (9)	3.70 (2)	—
B8†	1000 B.Gls.	2.08 (3)	2.45 (2)	3.78 (5)	3.38 (3)	3.52 (7)	3.58 (3)	—	—
C3†	200 Bass and	1.04 (2)	3.00 (3)	3.85 (4)	4.04 (4)	3.80 (7)	4.26 (4)	4.21 (8)	—
C5†	1000 B.Gls.	2.94 (3)	2.66 (3)	2.12 (4)	3.35 (3)	3.41 (6)	3.57 (6)	4.02 (4)	—
C7†	100 Bass	1.02 (2)	2.64 (4)	2.52 (5)	2.94 (3)	2.97 (6)	3.16 (5)	—	—
C9*	30 Adult B.Gls.	1.70 (1)	2.17 (3)	2.96 (2)	3.37 (8)	3.38 (7)	3.37 (7)	3.01 (1)	3.10 (1)
C8*	100 Bass and	0.62 (1)	3.00 (3)	3.58 (8)	3.68 (6)	3.08 (7)	3.95 (4)	4.07 (7)	5.67 (1)
B9*	100 B.Gls.	—	3.04 (4)	3.10 (9)	3.23 (6)	3.14 (7)	3.30 (5)	3.06 (2)	—
B4†	200 Bass and	1.08 (4)	3.02 (3)	2.75 (4)	3.49 (4)	3.71 (7)	3.94 (6)	2.81 (2)	—
B7†	200 B.Gls.	1.99 (4)	3.78 (3)	3.32 (5)	3.42 (4)	2.86 (6)	3.32 (6)	3.35 (1)	—

A Comparison of the Average K Values in All Balanced Ponds and in All Unbalanced Ponds

Balanced ponds	(23) 1.77	(32) 2.80	(41) 2.96	(46) 3.25	(53) 3.38	(51) 3.62	(18) 3.73	—
Unbalanced ponds	(2) 1.26	(10) 2.73	(19) 3.21	(20) 3.42	(21) 3.20	(16) 3.54	(10) 3.38	(2) 4.40

† Balanced ponds.
* Unbalanced ponds.

TABLE 11

Comparison of the Average K Values of Bluegills for All Classes in Each Pond

	Balanced Ponds									Unbalanced Ponds		
	C4	C6	B5	B8	C3	C5	C7	B4	B7	C9	C8	B9
Average K Value......	3.17	3.17	2.77	3.13	3.45	3.15	2.54	2.97	3.14	2.88	3.46	3.14
	Average 3.05									Average 3.16		

balanced ponds than in the unbalanced ponds, the exceptions being classes 1.6″ to 2.5″ and 3.6″ to 4.5″.

Table 11 shows the average *K* value for all classes in each pond. Note that in the bluegills, contrary to the bass, the range of *K* values is a little higher in the unbalanced ponds. Note also that the *K* value of bluegills in pond B7 compares favorably with *K* values in the other ponds, while in the largemouth bass the *K* value for B7 is the lowest of all the balanced ponds. B7 as mentioned earlier, had an excessive number of intermediate bass and very few harvestable bass, all of which were in poor condition.

The relation of the average *K* value of all classes in each pond to the average number of zooplankters per liter compares more favorably in bluegills than in the largemouth bass, Table 9. Note that the unbalanced pond C8 had the highest *K* value and the greatest number of zooplankters per liter. Ponds C3, C4 and C6 also had high *K* values and high counts of zooplankters. The closer relation between *K* values and number of zooplankters for bluegills is to be expected since they are dependent on zooplankters and also on mature and immature aquatic insects for food.

AGE AND GROWTH STUDIES

The age and growth at each annulus were determined through the study of 319 largemouth bass from 2.12 inches to 16 inches in length, and 342 bluegills from 0.87 of an inch to 3 inches in length. These fishes were recovered by the draining of the ponds between 4/1/57 and 5/15/57. Scales from the different size groups were taken from above the lateral line a little anterior to the spiny dorsal fin. The scales were used to determine the date when the annulus was formed, the study of the annual growth, and the yearly increment for each class.

FORMATION OF THE ANNULUS IN THE LARGEMOUTH BASS

It appears that the annulus is formed in the largemouth bass after May 1st. Bass taken from ponds drained before May 1st, showed no annulus formation for 1957, while bass taken after this date, May 7, showed the formation of an annulus near the margin of the scale, Tables 12, 13, 14, 15, and tables 16, and 17, respectively.

TABLE 12

Length Range, Average Length, Yearly Increment at Each Annulus, and Total Length in Inches When Caught

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Largemouth Bass				**Pond C7**			**When Drained—4/3/57**	
1956	10	Range	4.5–5.0	No annulus present				4.5–5.0
1955	6	Range		2.2–3.0				5.87–6.5
	6	Average		2.52				
		Increment		2.52				
1954	13	Range		2.6–8.0	5.0–10.4			7.75–11.75
	13	Average		4.77	6.92			
		Increment		4.77	2.15			
1953	9	Range		6.0–9.1	8.2–12.2	9.6–13.6		12.75–16.0
	9	Average		7.9	9.88	11.7		
		Increment		7.9	1.98	1.82		
Largemouth Bass				**Pond C9**			**When Drained—4/1/57**	
1956	5	Range	2.25–3.25	No annulus present				2.25–3.25
1955	12	Range		3.0–6.0				5.25–7.75
	12	Average		3.57				
		Increment		3.57				
1954	4	Range		6.5–7.7	8.3–9.3			10.0–10.75
	4	Average		7.07	8.70			
		Increment		7.07	1.63			
1953	6	Range		5.58–8.8	7.5–12.2	9.4–13.5		11.5–14.5
	6	Average		7.31	9.66	11.2		
		Increment		7.31	2.35	1.55		
Bluegill				**Pond C7**			**When Drained—4/3/57**	
1956	5	Range	1.0–2.5	No annulus present				1.0–2.5
1955	3	Range		1.4–1.77				2.5–3.0
	3	Average		1.58				
		Increment		1.58				
1954	9	Range		0.6–2.5	2.3–4.3			3.25–5.0
	9	Average		1.64	3.22			
		Increment		1.64	1.58			
1953	7	Range		1.5–2.5	3.6–4.2	4.8–5.5		5.25–6.5
	7	Average		1.83	3.98	5.13		
		Increment		1.83	2.15	1.15		

TABLE 12—*Continued*

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Bluegill			Pond C9			When Drained—4/1/57		
1956	5	Range	1.25–2.62	No annulus present				1.25–2.62
1955	3	Range		2.8–2.9				3.37–3.75
	3	Average		2.83				
		Increment		2.83				
1954	10	Range		0.83–2.9	2.6–4.3			3.5–4.85
	10	Average		1.89	3.52			
		Increment		1.89	1.63			
1953	12	Range		0.57–4.1	2.6–4.9	4.0–6.2		5.5–8.0
	12	Average		1.58	3.92	5.25		
		Increment		1.58	2.34	1.33		

TABLE 13

Length Range, Average Length, Yearly Increment at Each Annulus, and Total Length in Inches When Caught

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Largemouth Bass			Pond B5			Drained 4/12/57		
1956	8	Range	2.5–3.75	No annulus formed				2.5–3.75
1955	7	Range		2.2–4.0				6.2–6.75
	7	Average		2.72				
		Increment		2.72				
1954				No reproduction				
1953	11	Range		3.8–7.5	5.8–10.5	7.01–12.8		8.75–13.25
	11	Average		5.49	8.16	10.4		
		Increment		5.49	2.67	1.26		

TABLE 13—*Continued*

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Largemouth Bass				Pond B8				Drained 4/10/57
1956	9	Range	2.47–5.25	No annulus formed				2.47–5.25
1955	4	Range		3.1–4.1				4.5–5.25
	4	Average		3.42				
		Increment		3.42				
1954				No reproduction				
1953	17	Range		4.9–7.1	6.4–8.5	7.9–11.6		9.5–14.5
	17	Average		6.11	8.12	10.4		
		Increment		6.11	2.01	2.28		
Bluegill				Pond B5				Drained 4/12/57
1956	4	Range	1.12–2.5	No annulus formed				1.12–2.5
1955	5	Range		1.4–2.0				2.5–3.5
	5	Average		1.77				
		Increment		1.77				
1954	3	Range		0.95–1.6	3.2–3.6			4.5–4.9
	3	Average		1.13	3.29			
		Increment		1.13	2.16			
1953	11	Range		2.0–2.4	3.0–4.7	4.5–6.3		5.75–6.9
	11	Average		2.19	3.89	5.29		
		Increment		2.19	1.7	1.4		
Bluegill				Pond B8				Drained 4/10/57
1956	5	Range	1.12–2.25	No annulus formed				1.12–2.25
1955	4	Range		1.4–1.85				2.75–3.25
	4	Average		1.66				
		Increment		1.66				
1954	7	Range		1.05–2.1	2.2–3.6			3.5–4.9
	7	Average		1.41	2.73			
		Increment		1.41	1.32			
1953	6	Range		2.08–2.4	3.2–4.1	4.4–5.1		5.25–5.9
	6	Average		2.18	3.65	4.58		
		Increment		2.18	1.47	0.93		

TABLE 14

Length Range, Average Length, Yearly Increment at Each Annulus, and Total Length in Inches When Caught

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Largemouth Bass				Pond C8				Drained 4/18/57
1956	4	Range	2.25–2.62	No annulus formed				2.25–2.62
1955	9	Range Average		1.09–3.4 2.34				1.09–3.4
		Increment		2.34				
1954				No reproduction				
1953	10 10	Range Average		4.08–9.1 7.32	8.5–11.8 9.4	8.1–13.0 11.57		9.75–14.75
		Increment		7.32	2.08	2.17		
Largemouth Bass				Pond B9				Drained 4/15/57
1956	7	Range	2.35–4.5	No annulus formed				2.35–4.5
1955	11 11	Range Average		2.01–4.04 2.73				5.5–7.9
		Increment		2.73				
1954				No reproduction				
1953	15 15	Range Average		3.07–8.8 6.6	5.9–10.4 8.17	7.4–12.2 9.24		8.25–12.9
		Increment		6.6	1.57	1.07		
Bluegill				Pond C8				Drained 4/18/57
1956		Range	1.0–2.75	No annulus formed				1.0–2.75
1955	6 6	Range Average		1.4–2.1 1.68				2.75–3.5
		Increment		1.68				
1954	10 10	Range Average		0.76–1.5 1.14	1.7–3.4 2.86			3.75–5.1
		Increment		1.14	1.72			
1953	14 14	Range Average		0.92–2.7 1.81	3.08–5.0 4.41	4.2–6.1 5.94		5.1–7.75
		Increment		1.81	2.60	1.53		

TABLE 14—*Continued*

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Bluegill			Pond B9					Drained 4/15/57
1956	4	Range	2.0–2.25	No annulus formed				2.0–2.25
1955	7	Range		1.3–2.6				2.75–3.25
	7	Average		1.85				
		Increment		1.85				
1954	12	Range		0.71–1.8	2.7–4.0			3.5–5.25
	12	Average		1.02	3.19			
		Increment		1.02	2.17			
1953	10	Range		1.3–3.6	2.4–5.0	3.9–6.0		5.5–6.75
	10	Average		2.21	3.73	5.03		
		Increment		2.21	1.52	1.30		

TABLE 15

Length Range, Average Length, Yearly Increment at Each Annulus, and Total Length in Inches When Caught

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Largemouth Bass			Pond B4					Drained 4/25/57
1956	3	Range	4.62–5.0	No annulus formed				4.62–5.0
1955	10	Range		1.9–4.3				6.1–7.9
	10	Average		2.83				
		Increment		2.83				
1954				No reproduction				
1953	17	Range		3.7–6.6	5.5–9.5	6.9–10.6		8.25–11.5
	17	Average		5.5	7.7	9.22		
		Increment		5.5	2.2	1.52		
Largemouth Bass			Pond B7					Drained 4/23/57
1956	7	Range	2.12–3.0	No annulus formed				2.12–3.0
1955	8	Range		4.1–6.2				5.9–6.9
	8	Average		4.92				
		Increment		4.92				
1954				No reproduction				
1953	17	Range		3.9–5.5	5.7–7.8	6.9–11.7		8.5–14.5
	17	Average		5.38	6.74	8.05		
		Increment		5.38	1.36	1.31		

TABLE 15—*Continued*

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Bluegill			Pond B4					Drained 4/25/57
1956	8	Range	1.0–2.62	No annulus formed				1.0–2.62
1955	10	Range		1.6–3.0				2.75–4.9
	10	Average		2.51				
		Increment		2.51				
1954	5	Range		1.1–3.8	3.4–4.8			5.25–9.0
	5	Average		2.6	4.02			
		Increment		2.6	1.42			
1953	6	Range		2.25–3.6	3.4–5.5	5.3–7.0		6.25–7.75
	6	Average		3.05	4.6	5.95		
		Increment		3.05	1.55	1.35		
Bluegill			Pond B7					Drained 4/23/57
1956	5	Range	1.12–1.62	No annulus formed				1.12–1.62
1955	10	Range		0.8–1.8				2.0–4.1
	10	Average		1.4				
		Increment		1.4				
1954	7	Range		1.1–1.3	2.2–3.8			4.5–5.5
	7	Average		1.22	2.88			
		Increment		1.22	1.66			
1953	7	Range		1.7–2.4	3.7–4.7	5.1–5.7		5.75–6.75
	7	Average		1.8	4.1	5.29		
		Increment		1.8	2.3	1.19		

TABLE 16

Length Range, Average Length, Yearly Increment at Each Annulus, and Total Length in Inches When Caught

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Largemouth Bass				Pond C3				Drained 5/7/57
1956	4	Range		2.1–3.05†				2.87–3.25
		Average		2.7				
		Increment		2.7				
1955	14	Range		3.1–4.7	6.2–8.4†			6.5–8.75
	14	Average		3.9	7.18			
		Increment		3.9	3.28			
1954		No hatch						
1953	16	Range		3.1–7.2	5.1–9.5	7.1–10.6	9.0–12.7	9.5–12.9
	16	Average		5.14	7.07	8.9	10.05	
		Increment		5.14	1.93	1.83	1.15	
Largemouth Bass				Pond C5				Drained 5/1/57
1956	6	Range	3–3.75	No annulus formed				3.0–3.75
1955	15	Range		3.03–5.3				6.5–8.5
	15	Average		4.17				
		Increment		4.17				
1954		No reproduction						
1953	20	Range		5.2–8.5	7.1–10.1	8.4–11.2		9.75–12.5
	20	Average		6.29	8.09	9.9		
		Increment		6.29	1.80	1.81		
Bluegill				Pond C3				Drained 5/7/57
1956	2–4	Range	0.87–1.12	1.18–2.4†				0.87–1.12
	4	Average		2.0				2–2.75
		Increment		2.0				
1955	8	Range		1.2–2.2	2.7–4.3†			3.12–4.75
	8	Average		1.7	3.33			
		Increment		1.7	1.63			
1954	6	Range		1.2–2.7	3.0–3.7	4.4–5.2†		4.8–5.5
	6	Average		2.03	3.41	4.8		
		Increment		2.03	1.38	1.39		
1953	12	Range		1.5–3.0	3.2–5.0	4.2–5.9	5.5–7.1†	5.75–7.5
	12	Average		2.1	4.07	5.29	6.35	
		Increment		2.1	1.97	1.22	1.06	

TABLE 16—*Continued*

Lenght Range, Average Length, Yearly Increment at Each Annulus, and Total Length in Inches When Caught

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Bluegill				Pond C5				Drained 5/1/57
1956	3-5	Range	0.87-1.25	1.0-2.6†				0.87-1.25
	5	Average		2.1				1.62-2.75
		Increment		2.1				
1955	3	Range		2.2-2.4	3.0-3.5†			3.25-3.75
	3	Average		2.2	3.16			
		Increment		2.2	0.96			
1954	9	Range		1.2-2.4	3.1-4.4	4.0-5.5†		4.25-5.75
	9	Average		1.57	3.64	4.81		
		Increment		1.57	2.07	1.17		
1953	7	Range		1.3-4.3	3.3-5.1	4.7-6.4	5.6-7.1†	5.25-7.5
	7	Average		2.52	4.6	5.58	6.24	
		Increment		2.52	2.08	0.98	0.66	

† This Year's Annulus.

TABLE 17

Length Range, Average Length, Yearly Increment at Each Annulus, and Total Length in Inches When Caught

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Largemouth Bass				Pond C4				Drained 5/15/57
1956	5	Range		2.2–3.1†				2.37–3.37
	5	Average		2.46				
		Increment		2.46				
1955			No reproduction according to draining record. However, reproduction did occur according to seining record.					
1954			No reproduction					
1953	21	Range		3.2–6.7	4.9–9.8	6.9–12.3	7.7–13.5†	8.5–13.5
	21	Average		5.4	7.5	9.7	11.0	
		Increment		5.4	2.1	2.2	1.3	
Largemouth Bass				Pond C6				Drained 5/10/57
1956			No reproduction					
1955	18	Range		1.8–4.2	5.0–7.9†			5.5–8.5
	18	Average		3.06	6.3			
		Increment		3.06	3.27			
1954				No reproduction				
1953	21	Range		3.3–6.9	4.8–9.7	6.5–11.5	8.2–12.3†	8.5–12.9
	21	Average		5.3	7.2	9.1	10.3	
		Increment		5.3	1.9	1.9	1.2	
Bluegill				Pond C4				Drained 5/15/57
1956	8	Range		1.25–2.8†				1.25–3.0
	8	Average		1.98				
		Increment		1.98				
1955	3	Range		0.8–1.4	0.29–3.4†			3.25–3.5
	3	Average		1.1	3.16			
		Increment		1.1	2.06			
1954	8	Range		0.61–1.8	1.7–2.8	3.3–4.8†		3.5–5.1
	8	Average		1.1	2.21	4.1		
		Increment		1.1	1.11	1.89		
1953	9	Range		1.4–3.4	2.6–4.5	3.6–5.9	4.9–6.6†	5.25–6.9
	9	Average		2.05	3.56	4.85	5.75	
		Increment		2.05	1.51	1.29	0.9	

TABLE 17—*Continued*

Length Range, Average Length, Yearly Increment at Each Annulus, and Total Length in Inches When Caught

Year's Hatch	Number		Number of Annuli: None	1	2	3	4	Total Length When Caught
Bluegill				Pond C6				Drained 5/10/57
1956	8	Range		1.0–1.22†				1.2–2.75
	8	Average		1.7				
		Increment		1.7				
1955	1	Range		2.02	3.0†			3.2
	1	Average		2.02	3.0			
		Increment		2.02	0.98			
1954	10	Range		0.9–1.6	2.6–3.2	3.2–4.8†		3.5–5.25
	10	Average		1.06	2.78	3.77		
		Increment		1.06	1.72	0.99		
1953	10	Range		2.1–3.8	3.2–4.9	4.4–5.9	5.5–7.1†	5.5–7.1
	10	Average		2.5	3.89	4.94	5.79	
		Increment		2.5	1.39	1.05	0.85	

† This year's annulus.

FORMATION OF THE ANNULUS IN THE BLUEGILL

The annulus formation in the bluegill takes place between April 25th and May 1st. Bluegills recovered on and before April 25th showed no annulus formation for 1957, Tables 12, 13, 14, 15. Bluegills from ponds drained May 1st and later showed the formation of this year's annulus in all class groups, Tables 16 and 17.

ANNUAL INCREMENT IN LARGEMOUTH BASS

The annual increment in largemouth bass is also shown in Tables 12, 13, 14, 15, 16 and 17. The annual increment for largemouth bass follows the pattern of most fishes, with the greatest increase in length taking place during the first year, then decreasing during each successive year as the fishes increase in plumpness, or as the coefficient of condition increases. The same pattern is true in both balanced and in unbalanced ponds.

It is most interesting to compare the first year's growth of largemouth bass of the 1953 class, when the ponds were stocked for the first time, with the first year's growth for the successive years. The average growth of the 1953 class up to the formation of the first annulus was 6.5 inches. The length range was between 3.4 inches and 9.1 inches. The growths for this class in ponds C7 and C8 were 9.1

inches each, Tables 12 and 14. In two other ponds, C9 and B9, the bass reached a length of 8.8 and 8.9 inches respectively. In two of the above ponds, C7 and C9, the bass reproduced when one year old. These ponds were stocked with the Kentucky Ratio of 30 adult bluegills in the winter of 1952, and with 100 largemouth bass 2 to 2⅛ inches in July of 1953. The greatest growth of bass was in C7. One fish in this pond reached a length of 16 inches. The next pond showing greatest growth was C8, an unbalanced pond, with a length of 14.75 inches. Three ponds, C9, B7, and B8, showed growths of 14.5 inches. C9 was an unbalanced pond. The greatest growth in C3, the best balanced pond, was only 12.9 inches, Tables 12, 13, 14, 15, and 16, respectively.

ANNUAL INCREMENT OF THE BLUEGILLS

As in the largemouth bass the growth of the bluegills during the first year when the ponds were stocked in 1953 was greater than during the successive years, but not as great as in the largemouth bass, Tables 12, 13, 14, 15, 16 and 17. The average growth during the first year of the 1953 brood was only 2.13 inches. This is not much greater than the average growths shown in 1954, 1955 and 1956 broods, which were 1.48, 1.86 and 1.84 inches, respectively. One possible explanation of the poor growth rate of the 1953 bluegills as compared with the growth made by the 1953 bass is probably the lack of food present in the new ponds for the forage fishes, these fishes being dependent upon zooplankters and aquatic insects for their food supply. The low plankton count for 1953 bears out this supposition, Table 19.

The annual increment follows the same trend as that of the largemouth bass, the greatest growth occurring during the first year and decreasing during the successive years. However, the annual increment is much lower in the bluegill than in the largemouth bass. This is because the body of the bluegill is short, deep and compressed, as compared with the elongated body of the bass.

LENGTH AND WEIGHT RELATIONSHIPS, 1957

Table 18 gives the average length (by quarter inches) and weight relationships for 373 largemouth bass and 271 bluegills, recovered when the ponds were drained. For convenience the weights are given both in grams and in ounces. Note that in two instances, bass 9.25 inches in length and bass 10.25 inches in length, the weight is less than in bass 9 inches in length and 10 inches in length, respectively. This is due to the large numbers of bass of these sizes present in pond B7 that had a very low *K* average, Table 17. Note also that the only 8 inch bluegill taken weighed 3.6 ounces less than a bluegill 7.75 inches in length. This 8 inch fish came from C9, which was one of the unbalanced ponds.

ZOOPLANKTON STUDY

During 1953, 1954, 1955 and 1956 zooplankton was collected from each pond. Collections were made every two weeks during the summer and continued throughout the remainder of the year as the weather permitted. A standard plankton net, number 12 mesh, was used and towed an equal distance of 300 feet

TABLE 18

Length and Weight Relationships

Total Length in Inches	Largemouth Bass			Bluegill		
	Number of specimens	Weight		Number of specimens	Weight	
		Grams	Ounces		Grams	Ounces
0.75				2	0.12	0.004
1.0				10	0.13	0.0045
1.25				8	0.38	0.013
1.5				9	0.74	0.026
1.75				3	1.06	0.037
2.0				11	2.22	0.078
2.25	11	2.16	0.077	9	2.27	0.1
2.5	13	3.07	0.11	14	3.6	0.13
2.75	6	4.02	0.143	15	4.95	0.176
3.0	7	5.01	0.178	10	7.23	0.25
3.25	7	6.61	0.236	15	10.4	0.364
3.5	4	6.45	0.23	14	16.6	0.51
4.75	8	20.0	0.71	28	33.5	1.18
5.0	6	23.2	0.82	9	35.7	1.26
5.25	4	24.9	0.89	10	38.6	1.38
5.5	7	32.4	1.1	16	51.4	1.82
5.75	11	39.9	1.4	25	65.1	2.25
6.0	7	47.0	1.67	7	68.0	2.39
6.25	8	50.9	1.8	19	86.0	3.03
6.5	9	54.4	1.94	11	86.5	3.05
6.75	19	68.0	2.4	13	103.0	3.65
7.0	3	71.9	2.56	4	142.0	5.0
7.25	6	83.4	2.97	4	142.1	5.003
7.5	7	87.4	3.07	3	165.3	5.83
7.75	14	100.1	3.56	1	225.0	9.0
8.0				1	156.0	5.4
8.25	8	122.0	4.28			
8.5	15	131.5	4.69			
8.75	10	148.5	5.22			
9.0	10	155.11	5.67			
9.25	6	145.1	5.11			
9.5	8	179.3	6.32			
9.75	20	222.2	7.89			
10.0	4	221.2	7.84			
10.25	6	217.0	7.67			
10.5	9	259.1	9.14			
10.75	15	282.3	9.92			

TABLE 18—*Continued*

Length and Weight Relationships

Total Length in Inches	Largemouth Bass			Bluegill		
	Number of specimens	Weight		Number of specimens	Weight	
		Grams	Ounces		Grams	Ounces
11.0	6	306.9	10.78			
11.25	11	332.4	11.8			
11.5	9	345.0	12.7			
11.75	18	383.2	13.49			
12.0	6	402.7	14.18			
12.25	10	435.1	15.35			
12.5	5	450.8	15.88			
12.75	13	475.4	16.74			
13.0	1	468.0	16.49			
13.25	6	536.3	18.88			
13.5	5	570.0	20.11			
13.75	2	602.0	21.21			
14.0	2	702.0	24.7			
14.25	2	773.0	27.24			
14.5	5	833.0	29.8			
14.75	2	829.0	29.21			
15.0	1	949.0	33.49			
16.0	1	1205.0	42.49			
Total	373			271		

in all ponds. A Sedgwick Rafter counting chamber was used in counting the number of zooplankters present in each sample. No effort was made to determine the Protozoa present or the phytoplankton present. The main purpose of the work was to determine the relation between the numbers of zooplankters and pounds of fish produced in each pond, and also pond balance.

Table 19 is a summary of the total number and the average number of zooplankters for each pond during the year. The average number of zooplankters per liter for all the balanced ponds and the unbalanced ponds was determined in order to see whether there was any relation between total plankton for each pond and pond balance. Note, Table 20, that the average number in the balanced ponds was 142.7 per liter, and the average number in the unbalanced ponds was 160.3 per liter. Hence the total number of zooplankters per liter in the unbalanced ponds was greater. This is also the case in the relation of K value in bluegills and number of zooplankters, discussed earlier, where a high K value and greater number of zooplankters occurred in the unbalanced ponds.

TABLE 19

Number of Zooplankters per Liter. Number in Parentheses Represents Number of Collections Made

	1953		1954		1955		1956		Total
Pond	Total number	Average number	Total number	Average number	Total number	Average number	Total number	Average number	Average for each pond
C4†	422	(4) 105	2128.5	(17) 125.2	2841.5	(14) 203.0	3233.8	(13) 269.4	175.6
C6†	424	(4) 106	2146.7	(17) 126.3	2194.1	(14) 156.7	4344.6	(13) 362.0	187.7
B5†	11	(1) 11	1523.8	(17) 89.6	1818.9	(14) 129.9	2175.7	(13) 181.0	102.8
B8†	40	(1) 40	1666.7	(17) 98.0	2496.1	(14) 178.3	1850.4	(13) 154.6	117.5
C3†	874	(4) 219	2231.1	(17) 131.2	1844.6	(14) 131.8	3169.8	(13) 264.1	186.5
C5†	635	(4) 219	1738.8	(17) 102.3	2454.8	(14) 175.3	2175.7	(13) 181.3	154.2
C7†	354	(6) 50	2845.6	(17) 167.4	2488.1	(14) 177.7	2904.0	(13) 242.0	159.4
C9*	191	(6) 31	1928.2	(17) 113.4	2731.2	(14) 195.1	2929.3	(13) 244.1	146.1
C8*	29	(1) 29	1820.1	(17) 107.1	2301.1	(14) 164.4	4822.7	(13) 401.7	175.5
B9*	80	(1) 80	1516.5	(17) 89.2	2819.4	(14) 201.4	2718.8	(13) 226.5	149.2
B4†	32	(1) 32	1352.5	(17) 79.6	1883.4	(15) 134.5	1438.9	(13) 119.9	91.5
B7†	64	(1) 64	1166.3	(17) 68.6	1279.5	(14) 91.4	2612.6	(13) 217.7	110.4

† Balanced ponds.
* Unbalanced ponds.

Table 21 shows the relation between the total pounds of bass and total pounds of forage fishes and the number of zooplankters per liter in each pond. The best pond in terms of pounds of bass and number of zooplankters was C3 stocked with 200 bass and 1000 bluegills. This pond was second for pounds of bass and 2nd for zooplankters. C5, another pond stocked as above, came first and sixth. The least desirable ponds were B4 and B7, stocked with 100 bass and 100 bluegills. These ponds were eighth and twelfth, and twelfth and tenth, respectively.

For the bluegills, C4, stocked with 100 bass and 1000 bluegills was best, rating second for pounds and third for numbers of zooplankters. The worst pond was B4, stocked with 100 bass and 100 bluegills. This pond was twelfth for both pounds of fishes and numbers of zooplankters.

It is realized that pounds of zooplankters would have been a better criterion than number in computing relationships. Perhaps a weight relationship would have been closer.

KINDS OF ZOOPLANKTERS PRESENT DURING 1955

The kinds of zooplankters present in order of greatest abundance of each major group are given in Table 22. The Rotifers come first in abundance in all of the ponds. The most abundant form was Keratella cochlearis. The least abundant form of Rotifer was the Genus Noteus.

TABLE 20

Average Number of Zooplankters per Liter in Each Pond Each Year, and Total Average per Liter

Pond	1953		1954		1955		1956		Total Average per Liter
	No. of samples	Average no. per liter	No. of samples	Average no. per liter	No. of samples	Average no. per liter	No. of samples	Average no. per liter	
C4†	4	105	17	125.2	14	203.0	12	269.4	175.6
C6†	4	106	17	126.3	14	156.7	12	362.0	187.7
B5†	1	11	17	89.6	14	129.9	12	181	102.8
B8†	1	40	17	98.0	14	178.3	12	154.6	117.5
C3†	4	219	17	131.2	14	131.8	12	264.1	186.5
C5†	4	158	17	102.3	14	175.3	12	181.3	154.2
C7†	6	50.6	17	167.4	14	177.7	12	242.0	159.4
C9*	6	31.8	17	113.4	14	195.1	12	244.1	146.1
C8*	1	29	17	107.1	14	164.4	12	401.7	175.5
B9*	1	80	17	89.2	14	201.4	12	226.5	149.2
B4†	1	32	17	79.6	14	134.5	12	119.9	91.5
B7†	1	64	17	68.6	14	91.4	12	217.7	110.4

Total Average Per Liter for Balanced Ponds 142.7
Total Average Per Liter for Unbalanced Ponds 160.3

† Balanced ponds.
* Unbalanced ponds.

The most abundant form of Cladocera was the Genus Chydorus. The least abundant form was Holopedium gibberum.

Cyclops bicuspidatum was the most abundant of the Copepods. The least abundant form was the Genus Mesocyclops. The immature Nauplius stages of the Copepods were second to the Rotifers in abundance.

Only one form of the Phyllopods was present. Since most of these forms live in aquatic vegetation not many of these forms were taken in the tow.

Tables 23, 24, 25, 26, 27, 28, and 29 show the relative abundance of each of the above groups during 1953, 1954, 1955 and 1956. High and low peaks occur at irregular intervals during the year. These high and low peaks do not appear at the same time in all ponds. Some ponds may have a high count while other ponds may have a low count of the same forms at the same time.

THE RELATION OF WATER TEMPERATURE, *p*H, OXYGEN, CARBON DIOXIDE, TOTAL ALKALINITY AND TURBIDITY TO THE NUMBER OF ZOOPLANKTERS

Table 30 shows the relation of high and low counts of zooplankters to the chemical and physical data in each pond. There appears to be a definite relation between water temperature and the number of zooplankters in each pond. The

TABLE 21

Relation of Total Pounds of Bass and Total Pounds of Forage Fishes Taken by Angling, Seining, Test Netting and Draining, to the Average Number of Zooplankters per Liter in Each Pond

Ponds	Total Lbs of Bass	Order	Plankton order	Total Pounds Forage Fishes	Order	Plankton order	Average No. of Plankton	Order
C4	79.8	6th	3rd	260.45	2nd	3rd	175.6	3rd
C6	82.17	5th	1st	157.2	11th	1st	187.7	1st
B5	72.67	7th	11th	195.0	9th	11th	102.8	11th
B8	48.6	11th	9th	193.35	10th	9th	117.5	9th
C3	110.75	2nd	2nd	209.9	7th	2nd	186.5	2nd
C5	121.8	1st	6th	207.4	8th	6th	154.2	6th
C7	86.57	4th	5th	220.65	6th	5th	159.4	5th
C9	52.1	10th	8th	222.85	5th	8th	146.1	8th
C8	97.55	3rd	4th	381.15	1st	4th	175.5	4th
B9	62.3	9th	7th	240.45	3rd	7th	149.2	7th
B4	67.35	8th	12th	140.5	12th	12th	91.5	12th
B7	46.97	12th	10th	237.4	4th	10th	110.4	10th

TABLE 22

Kinds of Zooplankters in Order of Abundance in Twelve One Acre Ponds During 1955

ZOOPLANKTERS

Rotifera
- Kertatella cochlearis
- Epiphanes
- Brachionus capsuliflorus
- Polyarthra trigla
- Lecane
- Salpina spinigera
- Monostyla quadridentata
- Trichocerca
- Asplanchna
- Finilia longiseta
- Monostyla lunaris
- Brachionus angularis
- Pleosoma
- Brachionus furculatus
- Dinocharis pocillum
- Lindia truncata
- Lepadella
- Brachionus urceus
- Noteus

Cladocera
- Chydorus
- Alona
- Alonella

Cladocera—Continued
- Simocephalus
- Bosmina
- Moina
- Daphnia pulex
- Daphnia ?
- Sida crystallina
- Daphnia longispina galeata
- Scapholeberis mucronata
- Kurzia latissima
- Eurycercus lamellatus
- Holopedium gibberum

Copepoda
- Nauplius
- Cyclops bicuspidatus
- Eucyclops agilis
- Mesocyclops

Ostracoda
- Clamydochica

Phyllopoda

Midge Larvae

TABLE 23

Number of Zooplankters per Liter for 1953

Date	C3	C4	C5	C6	C7	C8	C9	B4	B5	B7	B8	B9
					Cladocera							
June 25					0.28		0.07					
July 8					7.5		0.69					
24					11.4		3.0					
Aug. 11	82.7	19.3	47.6	8.8	46.0		32.1					
26	50.8	7.8	4.2	2.0	4.3		2.2					
Sept. 4	1.9	2.4	15.6	1.9	—	—	—	4.04	—	14.0	—	12.3
Oct. 3	0.3	1.8	3.8	1.2	—	—	—	1.3	—	20.5	—	97.7
24	1.41	—	55.0	1.34	—	—	—	12.5	—	2.17	3.97	16.0
Nov. 7	—	1.17	29.9	—	1.0	47.4	—	16.3	—	12.5	—	—
21	1.4	1.43	—	—	—	—	—	13.6	—	5.9	1.3	2.0
Dec. 6	—	—	—	9.5	—	—	—	—	—	5.8	—	13.8
					Copepoda							
June 25					0.1		0.35					
July 8					2.2		0.34					
24					11.4		1.5					
Aug. 11	82.7	9.6	47.6	11.0	9.3		12.5					
26	50.8	32.6	36.8	2.0	4.3		2.2					
Sept. 4	49.0	41.0	29.3	41.5	1.9	5.4	1.8	8.0	1.0	6.0	—	14.4
Oct. 3	37.1	1.8	66.6	4.8	1.2	1.9	—	5.4	—	31.7	—	7.3
24	22.5	26.0	11.5	4.1	1.3	110.4	—	14.3	2.4	34.4	2.4	40.8
Nov. 7	67.4	24.3	8.4	3.6	1.0	47.4	—	2.0	6.6	2.0	15.6	—
21	65.3	15.6	14.4	14.1	—	17.3	13.6	2.8	11.7	1.4	20.6	22.5
Dec. 6	163.6	71.7	18.9	15.1	1.3	59.9	—	17.2	34.8	5.8	51.6	78.8
					Copepod Nauplius Stages							
June 25					2.2		0.13					
July 8					0.49		0.76					
24					18.3		6.0					
Aug. 11	36.5	9.6	28.5	22.1	—		2.1					
26	—	7.8	14.0	7.0	4.3	—	2.2					
Sept. 4	55.3	38.6	25.4	29.6	3.9	18.0	—	16.1	3.8	11.0	4.0	47.5
Oct. 3	13.6	7.5	43.6	4.8	1.2	—	1.4	2.5	1.1	147.6	27.6	3.7
24	22.1	19.5	—	1.0	0.5	48.1	2.6	16.7	2.4	24.3	13.6	24.9
Nov. 7	24.3	38.9	5.3	19.6	2.1	11.5	1.3	4.1	6.6	1.2	1.1	—
21	55.6	28.6	16.1	18.4	13.6	9.0	12.7	7.1	8.1	17.7	19.3	46.5
Dec. 6	92.1	32.6	44.0	80.4	2.6	43.4	33.0	43.6	36.9	5.8	41.3	53.0
					Ostracoda							
June 25					0.07		0.03					
July 8					0.13		0.23					
24					18.3		1.5					
Aug. 11	18.3	16.8	13.0	13.3	55.2		10.6					
26	—	3.9	16.0	2.0	—		2.2					
Sept. 4	—	2.4	3.9	—	1.9		—			14.0		

TABLE 23—*Continued*

Date	C3	C4	C5	C6	C7	C8	C9	B4	B5	B7	B8	B9
						Ostracoda—*Continued*						
Oct. 3	—	—	—	—	—	1.8	—	—	—	—	—	—
24	—	—	—	—	—	—	—	—	—	28.6	—	43.6
Nov. 7	—	—	3.52	—	—	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—	—	—	—	—	—
Dec. 6	—	—	—	—	—	—	—	—	—	—	—	—
						Rotifera						
June 25					10.4		5.4					
July 8					0.26		8.8					
24					27.4		10.8					
Aug. 11	73.5	26.5	47.6	22.1	48.3		23.8					
26	228.7	121.3	89.2	20.4	—		—					
Sept. 4	—	48.2	66.5	61.3	42.4	1.8	33.6	2.0	4.4	8.0	—	2.1
Oct. 3	9.7	12.0	6.4	2.1	12.3	15.0	21.0	2.5	13.1	1.4	17.9	25.8
24	25.4	11.9	1.4	14.4	14.3	20.9	96.3	1.3	3.6	14.3	20.6	26.2
Nov. 7	1.5	12.2	1.7	41.5	2.1	1.3	46.4	2.0	—	—	1.1	—
21	16.6	10.0	4.0	23.1	27.3	1.1	0.5	7.1	8.1	17.7	69.3	46.5
Dec. 6	6.9	4.4	4.4	1.4	9.1	2.1	—	3.1	4.9	—	8.5	6.9

Phyllopoda and midge larvae were so few that they are not included in the table.

greater abundance of zooplankters occurs between temperatures of 38 and 54 degrees Fahrenheit. The least numbers occur between 63 degrees and 74 degrees. This is true in all ponds with the exception of one in December, when the low count was at a water temperature of 42 degrees. Tables 23 to 29 inclusive show this drop in the number of zooplankters during the warm months of June, July and August. The fewer numbers taken at the higher temperatures may have been due to the vertical distribution. The zooplankters may have migrated to cooler water at the bottom of the pond and therefore were not taken in the plankton net.

Also, there seems to be a relation between the dissolved oxygen and the abundance of zooplankters. The greatest numbers of zooplankters were taken when the dissolved oxygen content was between 8.9 and 10.3 parts per million. Note one exception, pond B8, where the low count occurred when the oxygen was 9.6 parts per million. However, at this time the high count was also when the concentration of dissolved oxygen was greatest, 10.3 parts per million.

As is to be expected, the greater abundance of zooplankters occurred when the turbidity was high. This was true of all ponds with the exception of ponds C5, C6 and C4. Also, after the application of sodium arsenite, the decomposition of the plants caused the water to become quite turbid and a low plankton count resulted.

There appears to be no relation between the zooplankton count and the concentration of carbon dioxide or the total alkalinity in the ponds.

TABLE 24

Number of Zooplankters per Liter for 1954

Date	C3	C4	C5	C6	C7	C8	C9	B4	B5	B7	B8	B9
Cladocera												
Feb. 20	—	—	3.91	3.26	—	2.65	—	—	2.06	6.19	—	—
Mar. 13	14.4	19.6	18.9	23.5	1.52	—	2.2	0.2	—	—	—	—
27	—	—	—	—	—	4.87	—	—	—	16.2	—	2.56
Apr. 12	4.9	4.1	2.2	2.5	2.3	2.2	4.5	2.0	1.8	2.1	1.9	—
24	2.2	2.1	2.0	4.2	34.8	35.5	4.8	19.0	27.7	2.2	8.3	1.9
May 15	6.1	24.8	18.6	4.1	12.8	4.0	13.7	6.1	2.0	4.0	—	2.0
June 17	31.8	11.9	32.2	10.1	18.7	9.8	8.1	12.9	5.3	40.4	12.4	50.9
July 6	37.0	—	—	1.0	—	2.1	—	2.1	—	2.1	—	2.1
19	71.6	—	2.1	—	—	—	—	—	—	—	—	—
Aug. 11	2.0	—	—	—	4.0	—	—	1.9	—	9.8	2.0	—
23	—	—	—	—	1.8	—	3.8	14.1	11.3	18.3	1.8	1.8
Sept. 3	6.3	—	—	—	3.9	—	14.0	98.9	9.8	20.2	4.2	2.0
14	4.2	4.0	2.1	8.0	2.0	6.5	7.3	2.0	2.0	20.0	7.9	25.8
Oct. 8	13.7	41.1	38.4	11.4	18.7	19.8	47.3	19.3	—	1.7	10.4	18.6
29	7.4	2.1	12.0	4.0	11.3	5.6	7.1	8.0	9.6	6.3	3.8	9.7
Nov. 12	—	20.8	19.6	4.0	15.7	5.9	7.8	28.2	13.8	5.9	8.3	5.8
26	11.4	29.6	12.4	13.4	15.1	9.7	21.7	17.4	13.5	8.0	1.9	3.7
Copepoda												
Feb. 20	61.04	40.08	31.3	133.0	11.86	74.26	33.86	123.5	59.9	17.3	42.9	157.56
Mar. 13	5.86	35.67	59.0	65.5	16.09	95.1	123.9	30.56	47.3	6.52	49.3	228.3
27	14.4	19.5	18.9	23.5	15.7	32.0	77.9	39.6	46.0	27.4	66.5	18.6
Apr. 12	159.7	118.5	67.2	197.2	66.0	133.9	117.4	30.3	38.8	29.2	126.7	31.0
24	33.3	21.0	64.7	61.1	155.1	99.8	142.4	75.9	167.3	50.0	53.7	45.4
May 15	10.1	62.0	8.3	89.9	122.3	5.9	11.7	12.3	5.9	8.0	12.8	11.9
June 17	26.2	4.0	39.7	22.2	—	5.9	4.0	3.7	1.83	4.0	10.3	13.7
July 6	—	2.1	0.2	1.9	0.9	4.1	8.1	2.1	—	2.1	—	4.1
19	5.8	1.9	—	—	5.4	8.1	6.1	—	—	4.1	—	11.9
Aug. 11	2.0	2.0	5.8	6.3	11.9	2.0	14.8	3.8	3.8	11.7	7.9	8.1
23	1.9	1.8	14.8	3.7	7.4	14.3	20.8	2.0	11.3	1.8	3.7	18.5
Sept. 3	12.0	10.2	28.0	5.7	42.6	14.0	54.0	7.9	2.0	8.1	4.2	14.3
14	4.2	2.0	30.1	14.0	15.7	10.9	46.9	4.1	7.9	2.0	4.0	8.6
Oct. 8	17.3	6.2	34.1	4.0	9.5	1.9	14.3	—	4.3	4.2	—	5.8
29	9.8	11.7	18.1	11.4	39.3	5.9	25.8	15.9	4.6	—	6.1	—
Nov. 12	17.3	1.5	17.6	7.9	4.0	2.0	9.8	1.8	—	1.9	—	1.9
26	—	1.9	14.4	9.5	20.8	—	39.5	1.6	15.5	15.8	4.0	5.5
Nauplius Stages of Copepoda												
Feb. 20	41.8	113.2	42.6	33.9	7.9	119.1	24.9	58.0	84.6	18.5	134.8	137.1
Mar. 13	46.9	71.7	104.0	232.9	41.0	149.5	115.2	122.3	122.6	68.6	347.5	74.4
27	39.7	36.9	18.9	145.5	29.3	56.0	51.0	79.1	92.4	69.4	123.9	10.4
Apr. 12	59.0	88.3	53.7	79.8	81.4	87.8	131.1	20.9	64.7	66.8	83.2	33.3
24	28.0	18.7	58.6	96.0	270.8	55.4	137.5	50.6	254.2	48.3	78.5	22.7
May 15	50.5	80.5	33.0	33.5	20.1	2.0	17.6	10.2	4.0	10.0	1.8	27.7
June 17	104.7	89.0	244.0	190.0	32.4	39.1	8.1	24.0	3.6	70.8	52.8	215.7
July 6	1.8	8.3	0.2	3.9	3.4	4.1	6.1	2.1	—	6.3	2.1	—
19	1.9	—	—	2.0	5.6	2.0	6.1	—	—	—	2.0	4.0
Aug. 11	7.8	24.0	1.9	25.3	11.9	10.0	21.1	1.9	9.6	11.7	7.9	8.1
23	5.6	1.8	1.8	1.8	5.5	1.8	1.9	1.9	5.7	1.8	1.8	18.4
Sept. 3	6.0	10.2	4.0	5.7	15.9	6.2	6.0	2.0	2.0	—	8.3	12.2
Oct. 8	7.4	4.1	8.0	30.0	52.1	9.3	42.8	32.5	23.4	12.7	19.1	5.8
29	3.9	1.9	9.0	53.8	44.9	21.8	25.8	15.9	16.1	10.4	12.2	9.8
Nov. 19	58.7	20.8	17.6	55.4	13.1	17.9	7.8	7.0	5.9	23.2	—	7.7
26	17.0	4.0	15.4	32.5	64.2	4.8	27.3	4.6	15.5	15.8	4.0	5.5

The ponds were treated with sodium arsenite on June 29. Note the drop in number of zooplankters after this date.

TABLE 25

Number of Zooplankters per Liter Continued, for 1954

Date		C3	C4	C5	C6	C7	C8	C9	B4	B5	B7	B8	B9
							Ostracoda						
Feb.	20	2.34	—	—	—	—	—	—	—	—	—	—	—
Mar.	13	—	—	—	—	—	—	—	—	—	—	—	—
	27	—	—	—	—	—	—	—	—	—	—	—	—
Apr.	12	—	—	—	—	—	—	—	—	—	—	—	—
	24	—	—	—	—	—	—	—	—	—	—	—	—
May	15	—	—	—	—	—	—	—	—	—	—	—	2.0
June	17	1.9	—	—	—	1.9	—	—	—	1.8	8.1	22.6	5.9
July	6	3.5	2.1	5.9	—	2.4	—	—	—	—	12.5	—	4.1
	19	—	—	4.2	2.0	1.9	4.0	4.1	—	2.0	8.2	2.0	5.9
Aug.	11	—	—	1.9	—	2.0	—	2.1	—	—	3.7	—	—
	23	3.7	1.8	3.7	3.7	1.8	7.1	1.9	6.0	1.9	1.8	—	1.8
Sept.	3	6.0	6.1	4.0	1.9	—	4.2	2.0	2.0	2.0	—	8.3	12.2
	14	2.1	—	—	—	—	2.2	8.5	—	—	2.0	—	6.5
Oct.	8	2.5	4.1	4.0	—	—	—	—	1.8	—	8.4	1.9	—
	29	5.9	1.9	6.8	—	—	—	4.3	—	—	—	—	1.0
Nov.	19	2.2	—	—	—	—	—	—	1.8	—	—	—	—
	26	—	1.9	—	—	—	—	—	—	—	—	—	—
							Rotifera						
Feb.	20	337.9	114.4	5.9	5.2	100.9	11.0	3.56	5.0	4.1	6.2	20.4	18.0
Mar.	13	29.3	71.6	9.0	24.8	263.8	2.4	2.1	—	1.5	10.4	9.7	2.6
	27	162.7	121.7	28.3	82.1	429.4	58.0	168.7	162.2	166.0	158.9	28.8	2.7
Apr.	12	—	—	6.7	51.1	183.8	54.9	20.0	10.1	24.0	4.2	32.2	—
	24	17.2	505.0	12.1	2.1	152.9	2.2	19.3	8.4	4.1	—	18.6	20.8
May	15	32.3	8.5	14.0	14.3	5.5	11.9	43.0	4.1	15.8	2.0	12.8	19.8
June	17	58.0	19.8	27.1	30.5	3.8	15.7	8.1	35.1	1.8	2.0	20.7	7.8
July	6	28.2	27.1	13.8	5.8	—	12.4	14.2	12.4	6.0	10.4	6.3	14.5
	19	57.8	29.9	4.2	22.2	1.9	6.0	4.1	2.1	6.1	2.0	26.8	13.8
Aug.	11	25.4	18.0	21.8	12.7	7.9	6.0	14.8	32.9	38.3	15.7	15.8	10.1
	23	18.7	10.7	1.8	5.5	9.2	3.6	3.8	6.0	3.8	16.4	1.8	7.4
Sept.	3	21.7	20.4	25.7	24.0	7.7	12.4	—	98.9	3.9	10.1	8.5	8.2
	14	197.4	38.0	39.9	32.0	39.1	15.2	21.3	36.8	27.7	26.0	2.0	10.8
Oct.	8	49.6	24.8	40.0	40.0	49.2	142.1	5.3	50.5	61.8	48.5	34.4	23.2
	29	5.9	21.5	2.3	3.3	5.6	2.0	4.3	3.9	4.6	3.5	6.3	4.1
Nov.	19	8.7	3.8	5.9	17.8	4.0	7.9	5.9	3.5	7.9	5.8	10.3	7.7
	26	7.7	11.8	7.7	5.7	5.6	1.9	5.9	6.3	9.6	2.0	8.0	11.6

AQUATIC VEGETATION AND ITS CONTROL

Submerged vegetation became quite abundant during the first summer of the new ponds. Several species of Potamogeton were present in all of the ponds. During the winter and spring months Potamogeton crispus was the most abundant form. This species did not present any control problems since it died and disintegrated when the warm weather arrived in June. The next most abundant of the Potamogetons was the species americanus. This plant was controlled

TABLE 26

Number of Zooplankters per Liter for 1955

Date		C3	C4	C5	C6	C7	C8	C9	B4	B5	B7	B8	B9
							Cladocera						
Jan.	1	1.8	102.8	10.8	—	1.9	7.3	5.5	—	—	—	0.2	1.6
Apr.	16	48.0	8.2	15.9	10.1	13.2	93.9	28.3	3.7	—	—	4.1	8.4
	30	59.1	26.6	19.6	23.7	11.7	245.9	19.6	21.7	6.5	19.6	8.9	8.7
May	13	41.3	4.3	—	—	8.7	8.7	15.2	19.6	6.5	2.0	2.2	10.9
	27	23.9	6.5	17.4	6.5	4.3	4.3	6.5	4.3	28.3	2.2	—	6.5
June	17	21.7	13.0	26.1	37.0	19.6	15.2	10.9	6.1	2.2	4.3	15.2	13.4
July	1	26.1	4.3	6.5	17.4	2.2	8.7	26.1	13.0	—	4.3	4.3	8.7
	26	6.5	2.2	—	4.3	2.2	4.3	2.2	8.7	4.3	4.3	2.2	—
Aug.	11	4.3	2.2	—	—	—	2.2	—	26.1	2.2	—	—	17.4
	25	15.2	—	—	—	2.2	4.3	6.5	13.0	—	—	17.4	21.7
Sept.	9	4.3	2.2	15.2	2.2	30.4	8.7	—	15.2	6.5	2.2	13.0	15.2
Oct.	10	26.1	4.3	39.1	19.6	6.5	16.2	—	11.1	—	2.2	15.2	4.3
	26	74.8	15.2	10.9	8.7	2.2	6.5	4.3	6.5	6.5	2.2	32.6	4.3
Nov.	14	97.8	30.4	17.7	13.0	—	26.1	13.0	2.2	6.5	32.6	28.3	2.2
							Copepoda						
Jan.	7	—	3.7	16.2	1.8	23.9	21.9	1.8	1.2	—	18.0	—	—
Apr.	16	8.0	8.2	91.6	137.8	39.7	92.9	139.5	8.3	2.1	6.1	6.7	65.4
	30	28.4	11.0	72.4	71.5	70.4	17.0	247.5	23.9	8.7	6.5	6.7	23.8
May	13	2.2	2.2	78.3	147.8	8.7	—	2.2	19.6	6.5	—	2.2	15.2
	27	6.5	—	4.3	47.8	30.4	2.2	19.6	6.5	4.3	4.3	2.2	—
June	17	15.2	2.2	41.3	80.4	39.1	15.2	15.2	2.1	2.2	2.2	6.5	—
July	1	8.7	8.7	2.2	—	15.2	2.2	—	2.2	6.5	8.7	2.2	2.2
	26	8.7	—	—	—	2.2	13.0	2.2	6.5	—	—	4.3	2.2
Aug.	11	8.7	6.5	2.2	—	4.3	2.2	2.2	8.7	—	—	2.2	4.3
	25	13.0	2.2	—	2.2	—	13.0	6.5	13.0	—	—	6.5	6.5
Sept.	9	13.0	4.3	—	2.2	4.3	4.3	2.2	—	2.2	4.3	2.7	10.9
Oct.	10	2.2	—	—	—	2.2	6.5	—	6.7	2.2	15.2	2.2	4.3
	26	8.7	—	6.5	4.3	6.5	6.5	15.2	6.5	—	6.5	4.3	8.7
Nov.	14	1.3	—	—	4.3	28.3	6.5	2.2	—	—	10.9	6.5	2.2
							Nauplius Stages of Copepoda						
Jan.	7	16.0	1.9	3.6	1.8	38.3	84.0	27.7	11.6	3.6	123.3	0.2	3.3
Apr.	16	74.0	106.3	187.7	272.5	151.3	87.7	590.3	84.7	45.9	118.5	30.7	331.1
	30	88.9	106.4	191.7	206.3	64.6	29.7	110.4	219.6	58.7	54.3	66.5	202.2
May	13	13.0	43.5	17.4	8.7	43.5	28.3	56.4	104.3	52.2	72.4	50.0	78.3
	27	107.8	21.7	89.1	100.0	139.1	26.1	84.8	130.4	97.8	65.2	76.1	28.3
June	17	46.1	147.8	402.2	206.5	113.0	152.2	123.9	114.4	176.1	110.9	91.3	8.7
July	1	21.7	34.8	8.7	17.4	158.7	54.3	46.1	17.4	37.0	17.4	6.5	4.3
	26	4.3	63.0	17.4	6.5	80.4	69.6	17.4	132.0	8.7	8.7	78.3	6.5
Aug.	11	6.5	73.9	17.4	34.8	17.4	45.7	2.2	123.9	13.0	10.9	26.1	19.6
	25	6.5	84.8	21.7	54.3	145.7	34.8	115.2	78.3	34.8	12.4	73.9	71.7
Sept.	9	13.0	52.2	17.4	52.2	110.9	89.1	82.6	71.7	23.9	65.2	58.7	39.1
Oct.	10	4.3	69.6	6.5	—	180.4	104.3	89.1	15.5	23.9	52.2	34.8	28.3
	26	2.2	154.3	4.3	21.7	94.5	102.2	34.8	30.4	15.2	19.6	17.4	37.0
Nov.	14	8.7	169.6	4.4	30.4	71.7	97.8	108.7	65.2	6.5	45.7	45.7	150.0

TABLE 26 (*continued*)

Date	C3	C4	C5	C6	C7	C8	C9	B4	B5	B7	B8	B9
						Ostracoda						
Jan. 7	—	1.9	—	—	—	—	—	—	—	—	—	—
Apr. 16	—	—	—	—	—	—	—	—	—	—	—	—
30	—	4.4	—	4.1	0.6	8.5	—	—	—	2.2	4.4	—
May 13	6.5	—	2.2	6.5	—	—	—	—	—	—	—	—
27	—	—	—	—	—	—	—	—	—	—	—	—
June 17	13.0	—	—	8.7	2.2	4.3	—	—	—	—	2.2	—
July 1	6.5	—	—	—	—	—	7.2	2.2	—	17.4	—	—
26	4.3	2.2	—	2.2	2.2	4.3	4.3	2.2	2.2	13.0	—	4.3
Aug. 11	2.2	2.2	—	—	—	—	28.3	4.3	—	2.2	—	2.2
25	4.3	15.2	2.2	—	—	2.2	4.3	—	—	—	2.2	2.2
Sept. 9	—	—	4.3	—	—	—	2.2	—	2.2	—	—	2.2
Oct. 10	—	—	2.2	26.1	—	—	—	—	—	—	—	—
26	—	—	—	—	—	2.2	—	—	—	—	—	—
Nov. 14	23.9	2.2	—	—	—	—	—	—	—	2.2	—	—

easily by the application of standard sodium arsenite solution in the recommended dose of 5½ gallons per acre foot. Within a week after the application the plants disintegrated causing the water to become turbid. The turbidity in the ponds would continue for several weeks, and in some cases for the remainder of the summer. Treatment with sodium arsenite had a deleterious effect upon the zooplankters in the ponds. Tests were made before and after treatment with sodium arsenite in a few of the bass production ponds during 1954. After the application the zooplankton count dropped to zero in one pond and an examination of the stomach contents of the young bass showed no evidence of food.

TABLE 27

Number of Zooplankters per Liter Continued, for 1955

Date	C3	C4	C5	C6	C7	C8	C9	B4	B5	B7	B8	B9
						Rotifera						
Jan. 7	64.2	35.9	46.9	7.1	7.7	3.7	7.4	—	3.6	3.6	20.0	277.2
Apr. 16	8.0	508.8	7.8	8.1	51.1	—	24.3	169.3	133.5	45.0	396.4	44.3
30	83.2	39.9	39.1	14.3	111.5	29.7	7.2	76.1	808.7	91.3	55.4	13.0
May 13	30.4	956.5	1587.0	28.3	80.4	13.0	43.5	117.4	10.9	23.5	21.7	80.4
27	41.3	154.3	84.8	65.2	106.5	215.2	139.1	43.5	4.3	47.8	28.3	37.0
June 17	15.2	76.1	6.5	—	32.6	19.6	6.5	20.4	69.6	54.3	165.2	156.5
July 1	82.6	28.3	169.3	52.2	28.3	119.6	78.3	41.3	37.0	4.3	52.2	15.2
26	78.3	76.1	4.3	19.6	34.8	19.6	117.8	—	4.3	8.7	58.7	28.3
Aug. 11	100.0	139.1	28.3	26.1	321.7	45.7	32.6	58.7	15.2	10.9	7.8	39.1
25	102.2	39.1	23.9	106.5	100.0	56.4	84.8	28.3	32.6	32.6	130.4	197.8
Sept. 9	174.	43.5	69.6	30.4	23.9	43.5	19.6	15.2	19.6	10.9	56.5	19.6
Oct. 10	15.2	150.0	32.6	37.0	26.1	19.6	8.7	26.6	63.0	17.4	4.3	0.9
26	15.2	19.6	34.8	39.1	13.0	15.2	17.4	17.4	34.6	37.0	8.7	4.3
Nov. 14	—	21.7	141.7	8.3	30.4	26.1	17.4	56.5	184.8	13.0	13.0	4.3

TABLE 28

Number of Zooplankters per Liter for 1956

Date	C3	C4	C5	C6	C7	C8	C9	B4	B5	B7	B8	B9
Cladocera												
Feb. 27	15.4	6.8	8.7	6.5	—	2.2	30.4	—	4.3	55.4	—	6.5
Apr. 3	37.0	19.1	10.8	2.1	24.0	2.1	31.0	6.5	17.4	225.6	6.5	4.3
23	78.2	76.0	29.5	—	—	13.0	43.4	2.1	2.1	41.4	—	13.0
May 25	108.7	71.7	34.8	19.6	17.4	74.0	15.2	—	2.2	54.4	2.2	21.7
June 12	69.6	145.7	21.7	34.8	—	91.3	10.9	4.3	2.2	8.7	6.5	15.2
25	65.2	36.9	15.2	50.0	39.1	4.3	15.2	39.1	6.5	6.5	28.3	6.5
July 9	173.9	282.6	41.3	123.9	4.3	8.7	15.2	4.3	13.0	2.2	9.2	30.4
23	78.3	41.3	10.9	78.3	4.3	23.8	23.9	2.2	4.3	2.5	2.2	10.8
Aug. 7	47.8	54.3	13.6	2.2	—	6.5	4.3	—	10.8	8.5	10.8	10.8
20	208.7	156.5	55.0	—	2.1	6.5	4.3	2.1	—	21.7	38.6	30.4
Sept. 15	206.2	34.7	39.1	4.3	—	2.2	—	2.2	10.8	15.0	4.2	30.4
Oct. 10	52.1	66.1	65.1	6.5	—	—	—	15.2	12.9	32.1	6.6	43.4
Nov. 9	37.0	63.4	17.2	8.6	15.2	13.0	2.2	8.5	28.2	78.2	6.5	119.5
Dec. 18	108.6	10.8	6.5	21.7	8.5	2.2	58.7	8.3	6.7	13.0	2.2	19.5
Copepoda												
Feb. 27	76.0	228.2	239.1	32.6	30.4	13.0	84.7	32.6	54.3	21.5	19.5	47.8
Apr. 3	152.1	163.0	19.7	57.1	54.3	17.4	220.4	78.2	104.2	225.6	28.2	76.0
23	4.3	56.5	21.7	10.8	76.0	4.3	119.5	123.9	130.4	60.8	21.7	97.8
May 25	8.7	8.7	4.3	6.5	4.3	17.4	2.2	—	6.5	8.7	—	2.2
June 12	15.2	36.9	36.9	19.6	6.5	30.4	2.2	—	26.1	28.3	8.7	8.7
25	39.1	32.6	6.5	19.6	19.6	15.2	10.9	2.1	10.8	28.3	15.2	63.0
July 9	30.4	6.3	30.4	13.0	2.2	137.0	2.2	—	—	—	—	19.5
23	34.8	4.3	6.5	17.4	—	150.0	2.2	—	—	—	8.5	23.9
Aug. 7	56.5	13.0	6.5	—	—	43.4	8.6	—	2.1	19.5	8.5	8.6
20	26.0	8.7	23.9	15.2	—	26.0	10.8	2.2	8.7	31.2	4.3	—
Sept. 15	35.4	4.3	13.0	17.2	8.7	32.6	21.7	—	2.2	15.0	2.2	4.3
Oct. 10	19.5	6.8	15.2	34.7	—	6.5	—	—	—	17.3	2.2	4.3
Nov. 9	26.0	10.8	21.5	8.6	8.8	73.9	63.0	—	—	23.9	7.2	13.0
Dec. 18	15.2	6.5	4.3	21.7	30.4	6.6	39.1	2.2	4.3	2.2	—	13.0
Nauplius Stages of Copepoda												
Feb. 27	36.0	7.6	239.1	23.9	10.8	15.2	78.2	17.4	47.8	18.3	65.1	60.8
Apr. 3	38.7	191.3	76.0	121.7	69.5	32.6	183.7	180.4	169.5	134.0	71.7	180.4
23	26.0	21.7	52.1	30.4	34.7	32.5	39.1	217.3	165.2	19.5	8.2	119.5
May 25	10.9	13.0	8.7	28.3	19.6	32.6	23.9	—	8.7	2.2	21.7	15.2
June 12	15.2	93.5	28.3	173.9	176.0	17.4	93.5	28.3	139.1	28.3	65.2	37.0
25	43.5	28.3	67.4	91.3	102.2	84.7	132.7	18.5	48.7	17.4	65.2	110.9
July 9	34.8	80.4	39.1	180.9	58.7	297.8	110.8	8.5	12.2	4.3	45.6	93.0
23	21.7	67.4	17.4	80.4	6.9	165.2	45.6	2.2	2.2	19.5	26.0	47.8
Aug. 7	67.4	19.6	17.4	43.5	28.7	69.5	56.5	9.7	37.4	52.1	97.7	39.0
20	34.7	39.1	43.4	141.3	26.0	43.0	32.6	15.2	78.2	34.7	45.6	80.4
Sept. 15	35.4	80.4	13.0	56.5	95.6	54.3	32.6	19.5	47.8	44.7	56.5	19.5
Oct. 10	50.0	22.8	21.7	21.7	78.2	32.6	32.6	15.2	34.4	21.7	37.0	21.5
Nov. 9	34.4	171.7	25.8	115.2	15.2	115.2	181.7	60.8	71.7	45.6	45.6	32.6
Dec. 18	4.3	21.7	4.3	4.3	13.0	43.4	17.3	13.0	8.8	17.3	8.8	13.0

TABLE 29

Number of Zooplankters per Liter Continued, for 1956

Date	C3	C4	C5	C6	C7	C8	C9	B4	B5	B7	B8	B9
						Ostracoda						
Feb. 27	—	—	—	—	2.2	—	—	—	—	—	2.1	—
Apr. 3	—	—	—	—	—	—	2.8	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—
May 25	4.3	2.2	2.2	4.3	—	6.5	—	—	—	3.2	—	—
June 12	6.5	17.4	6.5	6.5	—	—	—	—	—	4.3	—	6.5
25	34.8	—	2.2	—	—	2.2	2.2	6.5	2.1	10.9	2.2	8.7
July 9	30.4	—	4.3	—	—	—	2.2	—	4.3	—	2.2	8.7
23	—	4.3	2.2	—	—	—	2.5	2.2	3.2	4.3	2.0	8.7
Aug. 7	8.7	8.7	2.2	2.2	—	—	—	—	—	—	—	—
20	4.3	2.1	6.5	—	—	—	—	—	—	4.3	—	—
Sept. 15	2.2	—	8.6	—	—	—	—	—	—	6.7	2.2	—
Oct. 10	—	—	4.3	—	—	95.6	—	—	—	2.2	—	—
Nov. 9	2.2	—	—	—	—	—	—	—	—	—	—	—
Dec. 18	—	—	—	—	—	—	—	—	—	—	—	—
						Rotifera						
Feb. 27	184.7	381.1	219.1	219.1	163.0	217.3	189.9	52.1	195.0	150.0	213.0	174.0
Apr. 3	140.0	134.0	403.3	508.7	322.1	782.6	121.7	39.1	4.1	21.7	139.1	158.6
23	—	217.0	539.0	939.1	458.6	884.3	108.6	15.2	23.9	6.5	156.7	532.6
May 25	10.9	95.6	58.7	97.8	281.2	273.9	330.4	191.3	184.8	15.2	165.1	186.9
June 12	19.6	15.2	63.0	82.6	310.9	91.3	158.8	67.4	143.6	161.0	87.0	95.7
25	226.1	152.2	58.7	69.6	80.4	315.1	45.4	7.3	84.7	45.6	87.0	97.9
July 9	213.0	21.7	26.1	108.7	65.2	299.8	41.3	13.0	26.0	34.4	43.4	32.4
23	39.1	15.2	32.6	35.6	41.3	69.5	39.1	41.3	39.1	24.2	39.1	32.6
Aug. 7	26.1	4.3	21.5	1.5	17.4	17.3	8.5	37.3	26.0	178.2	13.0	19.5
20	17.3	8.7	17.3	58.7	60.8	97.8	97.8	32.6	39.1	15.2	21.6	30.4
Sept. 15	84.2	18.3	17.2	67.3	28.2	31.7	13.0	4.3	8.7	47.9	10.8	19.5
Oct. 10	6.5	13.7	6.5	37.0	32.6	52.4	4.3	8.6	2.2	4.3	37.4	2.2
Nov. 9	4.3	17.2	13.0	6.5	2.2	39.1	2.2	4.3	13.0	10.8	32.6	13.0
Dec. 18	19.5	182.6	256.5	95.6	137.0	176.0	86.9	37.4	65.2	30.4	50.0	78.2

Sodium aresnite also causes a quick drop in the dissolved oxygen in the pond. Table 31 shows the effect before and after treatment in a 4½ acre pond treated with only 7 gallons of standard sodium arsenite solution.

An excessive use of sodium arsenite several weeks before the ponds are drained might result in a lowered production of bass due to starvation. Other submerged plants were Anacharis canadensis, Polygonon natans or smartweed, Ceratophyllum or coontail, and Myriophyllum or parrot feather. All of these plants were controlled easily with applications of sodium arsenite with the exception of Myriophyllum. Excessive doses of sodium aresnite had no effect upon this plant. One pond, C3, had an excessive growth of this plant. The only successful method of control was by cutting the stems near to the bottom with a scythe and floating the cut plants to the side of the pond and depositing them on the bank. Failure to

TABLE 30

The Relation of Temperature, pH, O_2, CO_2, Total Alkalinity and Turbidity During High and Low Zooplankton Count for Each Pond During 1956

Pond	Date	Water Temp.	pH	O_2	CO_2	Total Alkalinity	Number of Zooplankters		Turbidity
							Low	High	
C3	6/12/56	69	9.4	7.7	0	60	87		Clear
	4/ 2/56	50	8.8	9.3	0	94		715.2	3′
C5	8/ 6/56	74	9.0	4.9	0	74	63.3		1′
	4/30/56	54	9.6	10.3	0	64		632.6	3′
C4	8/ 6/56	74	9.4	5.8	0	64	104.4		Clear
	4/ 2/56	50	8.2	9.6	0	102		504.3	1′5″
C6	8/ 6/56	74	8.4	4.9	0	86	49.3		3′4″
	4/30/56	54	8.6	10.3	0	68		980.4	2′8″
C7	8/ 6/56	74	8.7	4.1	0	72	52.2		Clear
	4/30/56	54	8.6	9.4	0	82		569.5	2′6″
C9	9/10/56	64	7.8	2.0	4.0	128	67.3		1′6″
	4/ 2/56	50	8.0	9.6	0	92		527.6	1′6″
C8	9/10/56	64	8.5	7.3	0	124	110.8		1′
	4/30/56	54	9.3	9.5	0	54		943.7	1′8″
B9	10/ 6/56	63	8.3	7.7	0	102	76.9		3′
	4/ 2/56	50	7.8	8.9	2.7	120		419.5	1′6″
B4	7/ 9/56	72	8.6	6.6	0	80	32.6		2′
	4/30/56	54	8.9	9.0	0	70		278.2	Clear
B7	7/ 9/56	72	9.2	7.6	0	56	369		3′
	4/ 2/56	50	7.6	9.6	3.1	102		666.9	2′6″
B5	10/ 6/56	63	9.1	8.8	0	68	50		Clear
	4/30/56	54	8.8	9.1	0	72		323.9	2′6″
B8	12/18/56	42	7.8	9.6	0	124	60.8		3′6″
	2/18/56	38	7.6	10.3	0	120		300.0	1′6″

TABLE 31

Effect of Sodium Arsenite on the Dissolved Oxygen. Four and a Half Acre Pond Treated with Seven Gallons of Sodium Arsenite Solution on July 20. Treatment Covered One Third of the Pond. Oxygen Content Taken at the Kettle

Date	Oxygen ppm.	Date	Oxygen ppm.
July 20	6.4	July 29	1.8
July 24	0	Aug. 4	3.0

TABLE 32

Effect of Weed Cutting in a Moderate Amount on the Dissolved Oxygen

Date	Oxygen ppm.	Date	Oxygen ppm.
Pond C3—Vegetation Cut in One Third of the Pond on July 5			
June 20	8.2	Aug. 1	4.2
27	6.3	9	6.2
July 5	5.8	15	7.0
11	6.9	Sept. 6	4.9
18	7.8	12	5.2
24	6.0	26	7.1
Pond H3—Vegetation Cut in One Third of the Pond on August 8			
Aug. 6	6.2	Sept. 12	5.3
12	5.3	Oct. 9	8.8
Sept. 9	5.3	21	8.4

TABLE 33

Effect of an Excessive Cutting of Vegetation on the Dissolved Oxygen

Date	Oxygen ppm.	Date	Oxygen ppm.
Pond H1—Vegetation Cut Over Most of the Pond on June 20			
June 20	7.0	Aug. 15	2.8
July 7	1.45 At kettle	22	2.0
	2.0 At middle	29	3.4
July 11	1.3 Fish kill	Sept. 6	2.6
Aug. 1	5.1	13	3.0
9	4.1	Oct. 9	4.0
		21	8.4
Pond H5—Vegetation Cut Over Most of the Pond on August 8			
Aug. 1	6.8	Aug. 28	1.2
8	7.0	Sept. 6	1.8
15	2.2	12	2.4
22	1.1		

remove the plants from the pond after they were cut resulted in a more excessive growth due to rooting of the cut stems. The most abundant of the emergent forms was the cattail, Typha latifolia. A few Sagittaria gracilis, or arrowheads, were also present. These forms were easily controlled by cutting the stems near the bottoms with a long handled sickle.

Most of the Algae present consisted of the following forms: Oedogonium, Spirogyra, Hydrodictyon, Ulothrix, Chara, and Nitella. Most of these forms were controlled by applications of Delrad. After treatment with this chemical the Algae turned white in a few hours and disintegrated in about a week. After treatment with Delrad the zooplankton count showed a drop of about 50 percent.

THE EFFECT OF WEED CUTTING ON THE DISSOLVED OXYGEN

During the summer of 1955 a mechanical weed cutter was used to control the vegetation in several of the ponds. A moderate amount of cutting had little or no effect on the dissolved oxygen. An excessive amount of cutting resulted in a dangerous oxygen depletion and a fish kill. Tables 32 and 33 show the effects of weed cutting on the dissolved oxygen. As shown in Table 32 a moderate amount of weed cutting has little or no effect on the dissolved oxygen.

In both ponds H1 and H5 where the vegetation was cut over most of the pond there was a decided drop in the dissolved oxygen. In H1 there was a considerable fish kill. In H5 fresh water was supplied to the pond and this prevented a fish kill.

SUMMARY

1. The determination of pond balance through seining during early, middle, and late summer was only 41% accurate as compared with the draining records. The seining records and the draining records did not coincide in seven of the twelve ponds. Therefore in this work seining alone was not considered to be a good indication of pond balance. This may have been due to the failure of getting a good representative sample in some of the ponds because of an excessive growth of vegetation.

2. Based on the ranges of F/C, Y/C, A_T, A_F, I_F, and S_F, proposed by H. S. Swingle (1950), the best ratio in terms of being nearest to the mean of the desired ratios was the 200 bass and 1000 bluegills ratio stocked on 7/18/53 and 9/4/53, respectively. The second best ratio based on the above terms was the 200 bass and 200 bluegills ratio stocked on 8/26/53 and 9/4/53, respectively. The third and fourth best ponds were those stocked with 100 bass and 1000 bluegills on July and September, respectively.

3. Based on the best balance and the best in terms of pounds of harvestable fishes the ratio of 200 bass and 1000 bluegills was the best, ponds C3 and C5. These ponds rated first and third. The second best ratio was the 100 bass and 1000 bluegills ratio, ponds C4 and C6. These rated second and fifth. Note that in all these ponds the bass were stocked in July and the bluegills in September, rather than both bass and bluegills in the fall.

4. Of the twelve ponds, nine were in balance and three were unbalanced when drained. The three unbalanced ponds were C9, C8 and B9. Pond C9 was stocked with 30 breeder bluegills in September of 1952, and with 100 fingerling bass in July of 1953. Ponds C8 and B9 were stocked with 100 small bass and 100 small bluegills in September and November 1953, respectively.

5. The pond producing the greatest number of fish was pond C8, one of the unbalanced ponds stocked with 100 bass and 100 bluegills. The total number of pounds produced in this pond was 451.45 pounds. However, 338.35 pounds were small and intermediate forage fishes, and 1.3 pounds were small and intermediate bass, a very unbalanced condition. The next best ponds in terms of total pounds of fish were C4, C5 and C3, three of the best balanced ponds. See Tables 34 through 39, inclusive.

6. The coefficient of condition (K value) in largemouth bass is lowest in the

smaller classes, and becomes progressively greater as the fishes increase in length with the exception of a few cases. The lowest K value for bass was 1.48 in the 1.6″ to 2.5″ class. The greatest K value for bass was 2.71 in the 15.6″ to 16.15″ class. Also the K value for bass is greater in the balanced ponds with the exception of classes 10.6″ to 11.5″, 13.6″ to 14.5″ and 14.6″ to 15.5″.

When based on the average K value of all classes combined for balanced and unbalanced ponds, Table 8, the K value for balanced ponds is greater. The average in the balanced ponds was 2.12 as compared with 1.97 in the unbalanced ponds.

7. There appears to be very little relation between K value of bass and the number of zooplankters per liter. Pond C7 which is the first in K value is seventh in the number of zooplankters, while pond C5 which is second in K value is ninth in the number of zooplankters. Ponds C6, C3 and B9 were the only ponds where both K value and number of zooplankters were in the same order. These ponds rated second, fourth and fifth respectively.

8. As for the largemouth bass the K value for bluegills becomes progressively greater as the fishes grow in length. With the exception of the 7/8″ to 1.5″class the K value is greater in each class for the bluegill than for the largemouth bass. Also, as for the bass, with two exceptions, the average K value of the bluegill for each class is greater in the balanced ponds. The exceptions are classes 1.6″ to 2.5″ and 3.6″ to 4.5″.

When based on the average of all classes combined in balanced and unbalanced ponds, Table 11, the K value is a little higher in the unbalanced ponds. The average for the balanced ponds is 3.05 while the average in the unbalanced ponds is 3.16.

9. The relation of the average K value of all classes to the average number of zooplankters per liter in each pond for 1956 compares more favorably for the bluegills than for the bass. C8, an unbalanced pond, was first for both K value and number of zooplankters. Pond C3 rated second and fourth, C4 third, C6 third and second, and B9 fifth. The closer relation between K values and number of zooplankters in the bluegills is to be expected since they are dependent to a great extent on zooplankters for food, especially during the early years.

10. From a study of scales taken from largemouth bass before and after May 1st, it appears that the annulus is formed in the bass after May 1st.

11. The annulus formation in the bluegill takes place between April 25th and May 1st. Bluegills recovered before April 25th showed no annulus formation, while bluegills recovered after May 1st and later showed the formation of the year's annulus.

12. The average annual increment for the largemouth bass follows the same pattern as in most fishes with the greatest increase in length taking place during the first year then decreasing during each successive year.

The bass made a phenomenal growth during the first year when the ponds were stocked for the first time. Some bass in C7 and C9 stocked with the Kentucky ratio reached a length of 9.1 and 8.8 inches the first year. Bass reproduction occurred in both of these ponds when the bass were one year old. One other pond

showing a first year's growth of 9.1 inches was pond C8. However, no bass reproduction took place during the first year in this pond. The length range for bass in all ponds for the first year was between 3.4 and 9.1 inches.

13. The average annual increment for the bluegill the first year the pond was stocked was between 0.57 and 4.3 inches with an average growth of 2.13 inches. This average during the first year is not much greater than for the 1954, 1955 and 1956 broods. These increments for the first year were 1.48, 1.96 and 1.84 inches respectively.

The annual increment for the bluegill follows the same trend as that of the largemouth bass with the greatest growth occurring during the first year and decreasing during the successive years.

14. The length and weight relationships were computed from 373 largemouth bass and 271 bluegills recovered when the ponds were drained. The greatest growth for bass was 16 inches and a weight of 2.10 pounds. The greatest growth for bluegills was 8 inches. This fish weighed only 5.4 ounces as compared with a bluegill 7.5 inches in length which weighed 9 ounces.

15. The average number of zooplankters per liter in the unbalanced ponds was greater than in the balanced ponds, the average number being 160.3 and 142.7 per liter, respectively.

16. The relation of pounds of bass to the number of zooplankters is shown in Table 21. The best pond in the above terms was pond C3 stocked with 200 bass and 1000 bluegills. This pond rated second for zooplankters and for bass. C5 stocked as above came first and sixth. The least desirable ponds were B4 and B7 stocked with 100 bass and 100 bluegills. These ponds rated eighth and twelfth, and twelfth and tenth, respectively.

17. The best pond on the basis of pounds of bluegills and number of zooplankters was pond C4 stocked with 100 bass and 1000 bluegills. This pond rated second for pounds of bluegills and third for number of zooplankters. The worst pond on the above basis was pond B4 stocked with 100 bass and 100 bluegills. This pond rated twelfth for both pounds of fish and number of zooplankters.

18. The most abundant form of all zooplankters was the Rotifer. The next most abundant form was the Nauplius stage of the Copepods, followed by the adult Copepods, Cladocera and Ostracoda.

The most abundant and least abundant forms of Rotifers were Keratella cochlearis and Noteus, respectively.

The most abundant and least abundant forms of Copepods were Cyclops bicuspidatum and Mesocyclops, respectively.

The most and least abundant forms of Cladocera were Chydorus and Holopedium gibberum, respectively.

The most abundant form of Ostracoda was Clamydochica.

19. There appears to be a definite relation between temperature and number of zooplankters in each pond. The greater abundance of zooplankters occurs between temperatures of 38 and 54 degrees Fahrenheit. The least numbers occur between 63 and 74 degrees Fahrenheit.

20. There is also a relation between the dissolved oxygen and zooplankton

abundance. The greatest number of zooplankters occur between 8.9 and 10.3 parts per million of dissolved oxygen. They were least abundant between 2 and 8.8 parts per million of dissolved oxygen with the exception of pond B8 where the least number was at 9.6 ppm. However the greatest abundance in this pond was when the dissolved oxygen was 10.3 part per million.

21. The greater number of zooplankters also occurs when the turbidity is high with a few exceptions, ponds C5, C6, and C4.

22. There appears to be no relation between *p*H, CO_2, total alkalinity and the number of zooplankters.

23. The submerged vegetation became quite abundant during the first year of the new ponds. The vegetation included several species of Potamogeton, Anacharis canadensis, Polygonon natans or smartweed, Ceratophyllum or coontail, and Myriophyllum or parrot feather.

The emergent vegetation included the common cattail Typha latifolia and Typha augustifolia, some arrowheads Sagittaria gracilis, and some rushes Juncus.

The most abundant forms of Algae present were Hydrodictyon the water net, Spirogyra, Oedogonium, Chara, Nitella and Ulothrix.

24. The submerged vegetation was controlled with occasional applications of sodium arsenite. This chemical controlled most of the submerged forms with the exception of Myriophyllum. Repeated applications of sodium arsenite had no effect upon this plant. When it became excessive in the pond it was cut with a scythe and floated to the side and removed from the pond. Failure to remove the cut ends results in a more dense growth due to rooting of the cut ends. Potamogeton crispus, which is most abundant during the fall and winter months, was no problem at all since it disintegrated in June with the advent of the warm weather.

An excessive use of sodium arsenite caused a drop in the numbers of zooplankters and an increased turbidity in the ponds.

A mechanical weed cutter was used in some of the ponds to control the vegetation. An excessive amount of cutting resulted in a dangerous depletion of the dissolved oxygen and in one pond a fish kill. A moderate amount of cutting at intervals of several weeks had little or no effect upon the dissolved oxygen.

Cattails and arrowheads were controlled easily by cutting the stems near the root with a long handled sickle.

Delrad in the recommended doses was used to control the growth of Algae. This chemical was quite successful when used in air temperatures above 70 degrees Fahrenheit. After an application the Algae turned white in a few hours and completely disintegrated in the course of four or five days. However, Delrad caused a depletion in the zooplankton populations up to 50 per cent.

LITERATURE CITED

SWINGLE, H. S. Experiments with various rates of stocking Bluegills, Lepomis macrochirus Rafinesque, and Largemouth Bass, Micropterus salmoides (Lacépède), in Ponds. *Transactions, The American Fisheries Society*, September, 1950.

TABLE 34

Fishes Recovered per Acre on Draining

Pond C3—Drained 5/8/57 (Balanced Pond)
Stocked with
200 Largemouth Bass, 2″ to 2⅛″, 7/18/53
1000 Bluegills, 2″ to 2⅛″, 9/ 5/53

Number	Species	Pounds
108	Large largemouth bass	78.4
71	Intermediate largemouth bass	17.1
	No small largemouth bass below 6 inches	
575	Large bluegills	119.8
1,001	Intermediate bluegills	28.5
8,050	Small bluegills	40.5
11	Large warmouth bass	2.7
1	Large brown bullhead	1.0
1	Large carp	4.5
9,818	Totals	292.5

Ranges: F/C = 2.1, Within B; Y/C = 0.42, Within B; A_T = 69.84, Desired; A_F = 64.97, Desired; I_F = 14.46, Within; S_F = 25.05, Desired.

Pond C5—Drained 5/1/57 (Balanced Pond)
200 Largemouth Bass, 2″ to 2⅛″, 7/18/53
1000 Bluegills, 2″ to 2⅛″, 9/ 4/53

Number	Species	Pounds
106	Largemouth bass	73.8
131	Intermediate largemouth bass	32.0
25	Small largemouth bass	0.5
294	Large bluegills	40.9
1,403	Intermediate bluegills	58.5
95,260	Small bluegills	89.2
1	Large green sunfish	0.2
1	Large redear sunfish	0.2
1	Large white bass	0.2
1	Large gizzard shad	0.2
23	Intermediate warmouth bass	3.0
97,246	Totals	298.7

Ranges: F/C = 1.8, Within B; Y/C = 0.7, Within B; A_T = 39.76, Within B; A_F = 21.46 Within B; I_F = 21.44, Within; S_F = 46.24, Within A.

Balanced Populations (Swingle, 1950)

	Range	Desired Range
F/C	1.4 to 10.0	3.0 to 6.0
Y/C	0.02 to 5.0	1.0 to 3.0
A_T	33% to 90%	60% to 85%
A_F	18.2% to 96.6%	60% to 80%
I_F	Overlapped in balanced and in unbalanced ponds. Balanced ponds = 0 to 41%. Unbalanced ponds = 0 to 100%.	
S_F	0.4% to 80.9% Above 60% is considered an inefficient population.	15% to 40%

TABLE 35

Fishes Recovered per Acre on Draining, 5/14/57

Pond C4—(Balanced Pond)

Stocked with

100 Largemouth Bass, 2″ to $2\frac{1}{8}$″, 7/28/53

1000 Bluegills, 2″ to $2\frac{1}{8}$″, 9/17/53

Number	Species	Pounds
60	Large largemouth bass	59.2
6	Intermediate largemouth bass	2.42
609	Small largemouth bass	2.9
473	Large bluegills	72.5
3,698	Intermediate bluegills	101.2
7,732	Small bluegills	63.9
1	Brown bullhead	0.6
12,579	Totals	302.72

Ranges: F/C = 3.7, Desired; Y/C = 0.98, Desired; A_T = 44.3, Within B; A_F = 30.68, Within B; I_F = 42.48, Within; S_F = 26.82, Desired.

Pond C6—(Balanced Pond)

100 Largemouth Bass, 2″ to $2\frac{1}{8}$″, 7/28/53

1000 Bluegills, 2″ to $2\frac{1}{8}$″, 9/17/53

Number	Species	Pounds
64	Large largemouth bass	56.45
47	Intermediate largemouth bass	10.1
	No small largemouth bass	
293	Large bluegills	41.9
680	Intermediate bluegills	23.0
17,400	Small bluegills	77.3
18,484	Totals	208.75

Ranges: F/C = 3.6, Desired; Y/C = 1.1, Desired; A_T = 42.4, Within B; A_F = 29.46, Within B; I_F = 16.17, Within; S_F = 53.64, Within A.

TABLE 36

Fishes Recovered per Acre on Draining, 4/2/57

Pond C7—(Balanced Pond)

100 Largemouth Bass, 2″ to 2⅛″, 7/7/53

30 Breeder Bluegills, 11/11/52

Number	Species	Pounds
60	Large largemouth Bass	61.2
44	Intermediate largemouth bass	9.5
11	Small largemouth bass	0.5
392	Large bluegills	38.7
3,620	Intermediate bluegills	99.95
42,600	Small bluegills	68.0
1	Brown bullhead	0.5
46,728	Totals	278.35

Ranges: $F/C = 3.6$, Desired; $Y/C = 0.47$, Within B; $A_T = 46$, Within B; $A_F = 62$, Desired; $I_F = 40$, Within; $S_F = 32$, Desired.

Pond C9—(Unbalanced Pond)

100 Largemouth Bass, 2″ to 2⅛″, 7/7/53

30 Breeder Bluegills, 11/11/52

Number	Species	Pounds
41	Large largemouth bass	33.0
10	Intermediate largemouth bass	3.45
50	Small largemouth bass	0.35
320	Large bluegills	32.2
1,040	Intermediate bluegills	55.5
14,773	Small bluegills	111.25
2	Large redear sunfish	0.5
27	Small redear sunfish	0.25
2	Large green sunfish	0.8
341	Small green sunfish	2.0
7	Small warmouth bass	0.1
1	Large carp	6.25
16,614	Totals	245.65

Ranges: $F/C = 5.6$, Desired; $Y/C = 2.9$, Desired; $A_T = 30.01$, Below R; $A_F = 19.03$, Within B; $I_F = 26.57$, Desired; $S_F = 54.39$, Within A.

Balanced Populations (Swingle, 1950)

	Range	Desired Range
F/C	1.4 to 10	3.0 to 6.0
Y/C	0.02 to 5.0	1.0 to 3.0
A_T	33% to 90%	60% to 85%
A_F	18.2% to 96.6%	60% to 80%
I_F	Overlapped in balanced and unbalanced ponds. Balanced ponds = 0 to 41%. Unbalanced ponds = 0 to 100%.	
S_F	0.4% to 80.9% Above 60% considered inefficient population.	15% to 40%

TABLE 37

Fishes Recovered per Acre on Draining

Pond C8—Drained 4/18/57 (Unbalanced Pond)
100 Largemouth Bass, 2″ to 2½″, 9/23/53
100 Bluegills, 2⅛″ to 2½″, 11/9/53

Number	Species	Pounds
51	Large largemouth bass	80.0
16	Intermediate largemouth bass	1.0
57	Small largemouth bass	0.3
162	Large bluegills	31.3
879	Intermediate bluegills	33.75
22,682	Small bluegills	304.0
1	Large warmouth bass	0.5
2	Intermediate warmouth bass	0.1
30	Small warmouth bass	0.5
23,880	Totals	451.45

Ranges: F/C = 4.5, Desired; Y/C = 3.7, Within A; A_T = 26.94, Below R; A_F = 8.57, Below R; I_F = 9.11, Within; S_F = 82.1, Above R.

Pond B9—Drained 4/16/57 (Unbalanced Pond)
100 Largemouth Bass, 2″ to 2½″, 9/23/53
100 Bluegills, 2⅛″ to 2½″, 11/9/53

Number	Species	Pounds
46	Large largemouth bass	42.3
36	Intermediate largemouth bass	5.05
72	Small largemouth bass	0.45
91	Large bluegills	9.95
1,411	Intermediate bluegills	52.0
20,250	Small bluegills	167.0
21,906	Totals	276.75

Ranges: F/C = 4.8, Desired; Y/C = 3.4, Desired; A_T = 18.87, Below R; A_F = 4.34, Below R; I_F = 22.71, Within; S_F = 72.54, Within.

Balanced Populations (Swingle, 1950)

	Range	Desired Range
F/C	1.4 to 10	3.0 to 6.0
Y/C	0.02 to 5.0	1.0 to 3.0
A_T	33% to 90%	60% to 85%
A_F	18.2% to 96.6%	60% to 80%
I_F	Overlapped in balanced and unbalanced ponds. Balanced ponds = 0 to 41%. Unbalanced ponds = 0 to 100%.	
S_F	0.4% to 80.9%	15% to 40%

TABLE 38

Fishes Recovered per Acre on Draining, 4/24/57

Pond B4—(Balanced Pond)
200 Largemouth Bass, 2⅛", 8/26/53
200 Bluegills, 1⅞" to 2⅜", 9/4/53

Number	Species	Pounds
65	Large largemouth bass	39.2
71	Intermediate largemouth bass	12.9
	No small large mouth bass below 4"	
349	Large bluegills	47.3
440	Intermediate bluegills	21.7
52,325	Small bluegills	58.4
No count	Golden shiners	0.5
53,250	Totals	180.0

Ranges: $F/C = 2.4$, Within B; $Y/C = 1.1$, Desired; $A_T = 47\%$, Within B; $A_F = 37\%$, Within B; $I_F = 16\%$, Within; $S_F = 46\%$, Within A.

Pond B7—(Balanced Pond)
200 Largemouth Bass, 2⅛", 8/26/53
200 Bluegills, 1⅞ to 2⅜, 9/4/53

Number	Species	Pounds
4	Large largemouth bass	3.4
96	Intermediate largemouth bass	28.1
14	Small largemouth bass	0.1
171	Large bluegills	19.5
1,244	Intermediate bluegills	43.7
39,300	Small bluegills	81.2
3	Large white crappies	1.6
67	Large orange spotted sunfishes	7.5
No count	Small orange spotted sunfishes	1.0
No count	Small warmouth bass	2.9
No count	Intermediate green sunfishes	1.2
1	Large redear sunfish	0.3
7	Large gizzard shad	3.5
7	Large carp	63.0
40,914 plus	Totals	257.0

Ranges: $F/C = 7.0$, Within A; $Y/C = 2.6$, Desired; $A_T = 37\%$, Within B; $A_F = 41\%$, Desired; $I_F = 19\%$, Within; $S_F = 37\%$, Desired.

NOTE: If the large shad and carp were omitted this pond would be *unbalanced*.
$F/C = 4.4$, Desired; $Y/C = 2.2$, Desired; $A_T = 12.6$, Below R; $A_F = 11.9$, Below R; $I_F = 9.4$, Within; $S_F = 54.2$, Within.

TABLE 39

Fishes Recovered per Acre on Draining

Pond B5—Drained 4/12/57 (Balanced Pond)
100 Largemouth Bass, 2¼" to 3", 9/22/53
1000 Bluegills, 2" to 2⅛", 9/22/53

Number	Species	Pounds
55	Large largemouth bass	53.55
14	Intermediate largemouth bass	2.5
110	Small largemouth bass	1.0
318	Large bluegills	47.8
1,014	Intermediate bluegills	26.40
34,589	Small bluegills	109.0
36,100	Totals	240.25

Ranges: $F/C = 3.2$, Desired; $Y/C = 1.9$, Desired; $A_T = 42.2$, Within B; $A_F = 26.12$, Within B; $I_F = 13.66$, Within; $S_F = 59.56$, Within A.

Pond B8—Drained 4/10/57 (Balanced Pond)
100 Largemouth Bass, 2¼" to 3", 9/22/53
1000 Bluegills, 2" to 2⅜", 9/22/53

Number	Species	Pounds
40	Large largemouth bass	30.7
8	Intermediate largemouth bass	2.1
90	Small largemouth bass	0.55
400	Large bluegills	40.0
511	Intermediate bluegills	14.1
43,250	Small bluegills	124.5
2	Large yellow perch	0.3
2	Large brownbulls	1.75
44,303	Totals	214.0

Ranges: $F/C = 5.4$, Desired; $Y/C = 3.7$, Desired; $A_T = 33.03$, Within B; $A_F = 23.12$, Within B; $I_F = 7.8$, Within; $S_F = 68.9$, Within A. Inefficient.

Balanced Populations (Swingle, 1950)

	Range	Desired Range
F/C	1.4 to 10	3.0 to 6.0
Y/C	0.02 to 5	1.0 to 3.0
A_T	33% to 90%	60% to 85%
A_F	18.2% to 96.6%	60% to 80%
I_F	Overlapped in balanced ponds and unbalanced ponds. Balanced ponds = 0 to 41%. Unbalanced ponds = 0 to 100%.	
S_F	0.4% to 80.9%	15% to 40%
	Above 60% considered inefficient population.	

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